Study on electromagnetic environment of ±800 kV UHV DC and 1000 kV UHV AC parallel transmission lines

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Abstract. Aiming at the typical AC/DC parallel transmission lines which have been put into operation in China, the electromagnetic environment of parallel transmission lines is monitored and the interaction between AC and DC electromagnetic environment is analyzed. Monitoring results show that: The electromagnetic environment of UHV AC/DC parallel transmission lines meets the corresponding national standard limits. UHV DC transmission line has little influence on power frequency electromagnetic field, which is mainly affected by distance and wire height to ground. UHV AC transmission line may have a certain impact on DC composite field strength, and wind speed will have a greater impact on DC composite field strength.

1. Introduction
With the rapid development of local economy, transmission corridors are becoming increasingly scarce in economically developed areas, and the parallel erection of AC and DC lines is inevitable[1]. The smallest parallel spacing is less than 60m. Due to the coupling effect, the surface electric field of AC and DC parallel lines changes and superimposes, and form the so-called hybrid electric field, which leads to the complex hybrid electromagnetic environment of AC and DC parallel lines[2-10]. For the typical AC/DC parallel lines in operation, it is of great significance to select suitable locations, monitor the hybrid electromagnetic environment, grasp its actual level and study its interaction for the reasonable design of the follow-up UHV project and the evaluation of the AC/DC hybrid electromagnetic environment.

2. Measuring principle
2.1. Power frequency electromagnetic field
The parallel plate suspension probe is usually used in power frequency electric field measurement. The area of the corresponding part of the parallel plate is S (m²). In the uniform electric field with E (V/m), the surface charge of the plate is equal in quantity to the average displacement charge on the area.

\[ q = \varepsilon ES \]  

(1)

The current flowing through the plates is measured as follows:

\[ I = \frac{dq}{dt} = j_0\varepsilon ES \]  

(2)
Then, the measured electric field intensity is:

$$E = \frac{I}{\varepsilon \omega S}$$

(3)

For the power frequency (50Hz) electric field in the air, $\omega = 314$ rad/s, $\varepsilon = 8.85 \times 10^{-12}$ F/m, $S = 7.07 \times 10^{-4}$ m$^2$, so the effective value of electric field intensity on the ground can be obtained as follows:

$$E = 0.51 \times 10^4$$ (V/m)                                                            (4)

2.2. DC composite field [2-9]

The idea of DC electric field measurement is to make the total number of power lines on the sensor module change periodically, and the corresponding induced charges also change periodically. These periodically changing charges form measurable currents. According to these currents, the corresponding field strength can be measured. The measuring instrument of synthetic field strength is called field grinding.

The amount of accumulated charge is determined by equation (5):

$$q_s(t) = \varepsilon_0 E A(t)$$

(5)

Where $q_s(t)$ is the Charge on Static field grinding disc varying with time in C; $\varepsilon_0$ is the Dielectric coefficient of vacuum, $\varepsilon_0 = \frac{1}{36\pi} \times 10^{-9}$ F/M; $E$ is the Electric Field Intensity at Measured Points in V/m; $A(t)$ is the area of static field grinding disc exposed to electric field varying with time in m$^2$. The current corresponding to $q_s(t)$ is:

$$i_s(t) = \frac{dQ(t)}{dt} = \varepsilon_0 E \omega h^2 A_0 \sin(n wt)$$

(6)

Formula 6 is the basic basis for designing the physical size and amplifier multiples of field grinding sensors.

3. Monitoring points and working conditions of AC/DC parallel transmission lines

3.1. Monitoring points

The monitoring point is located in Qinyang City, Jiaozuo City, Henan Province. The parallel lines are the ±800kV UHV DC Tianzhong transmission lines and the 1000kV UHV AC Changnan I transmission lines. The distance between side conductors of parallel lines is 75m. The minimum height of Tianzhong transmission lines from the conductor to ground (soil) is 38m, and The minimum height of Changnan I transmission lines from the conductor to ground (soil) is 30m. The monitoring location is farmland and it is suitable for monitoring. The electromagnetic environment monitoring path is a road perpendicular to the parallel lines direction.

The situation of the transmission lines is shown in Figure 1. The monitoring path is arranged along the cement road below the lines.

The monitoring point starts at 50m on the west side of ±800 kV DC lines and ends at 50m on the east side of 1000 kV AC lines. The length of the monitoring path is 222m. According to the actual situation on the monitoring point, the measurement spacing is 2 m at 20m to 21m on the west side of ±800 kV DC lines and 24m to 20m on the west side of 1000 kV AC lines, and the other measurement spacing is 5 m. It is as shown in Figure 2.

The monitoring photos are shown in Figure 3.
3.2. Operation conditions of the transmission lines and meteorological conditions during monitoring

The monitoring time, meteorological conditions and operation conditions of the transmission lines are shown in Table 1.
Table 1. The monitoring time, meteorological conditions and operation conditions.

| monitoring time | meteorological conditions | operation conditions |
|-----------------|--------------------------|----------------------|
| Spring: 6 March 2018 | Temperature 7°C, RH 50.4%, Northeasterly wind 1.6m/s~2.1m/s | ±800 kV DC lines: positive electrode U=762.1kV, I=3348A; Negative electrode U=762.9kV, I=3349A. 1000 kV AC lines: U=1056.48kV, I=336.45A. |
| Summer: 11 July 2018 | Temperature 26.1°C, RH 78.9%, Northeasterly wind 0.7m/s~1.3m/s | ±800 kV DC lines: positive electrode U=+389kV, I=2378A; Negative electrode U=0kV, I=0A. 1000 kV AC lines: U=1053.18kV, I=448A. |

4. Monitoring results

4.1. Monitoring results of DC composite field intensity in spring and summer

HDEM-1 DC Synthetic Field Intensity Detector produced by Beijing Safety Test Technology Co., Ltd is used for DC Synthetic Field Intensity Measurement. The measuring range is -100 kV/m~+100 kV/m, the accuracy is 0.01 kV/m, and the working temperature is -40°C~60°C. The sampling time of each monitoring point is 200 seconds and the sampling interval is 2 seconds. A total of 100 groups are measured. Sort by absolute value size, find out the values that 95% of the data do not exceed (maximum) and 80% of the data do not exceed.

Comparing the measurement results in spring and summer, 95% and 80% confidence values in spring and summer are taken respectively. The variation trend of DC composite field along the measurement path is shown in Figure 4.

Figure 4. Distribution of DC composite field intensity along vertical lines in spring and summer.

From the distribution of DC synthetic field in spring and summer, it can be seen that:

1) The synthetic electric field of negative polarity is obviously larger than that of positive polarity in spring. The maximum value is 5.8kV/m in positive polarity and the maximum value is 20.15kV/m in negative polarity. Because the migration speed of positive and negative ions in the electric field is the same order of magnitude compared with the wind speed, even if the wind is very small (1m/s), the position of the maximum and minimum value of the synthetic electric field will move along the wind...
direction. When the wind speed is a little larger, the synthetic electric field will change greatly [10]. When monitoring, the wind direction is northeast, and the wind direction blows from positive pole to negative pole, which makes the space negative ions towards the negative pole and causes the synthetic field strength to increase. The value at 30m, 44 m, and 78m may be affected by the surrounding environment, such as plants, communication lines and so on.

(2) In summer, the operating conditions of DC lines are abnormal, and only the positive pole step-down operation result in the composite field strength on the side of negative conductor to be positive and the value is smaller than that in spring.

(3) In spring, the synthetic field strength values at 0-30m show an increasing trend. It may be influenced by 220 kV AC transmission lines on the West side. The influence of AC lines on the synthetic field strength needs further monitoring and research.

(4) Due to the different operating conditions of parallel lines in spring and summer, and the current UHV DC lines is still in step-down operation, the difference of DC synthetic field strength in spring and summer needs further study.

4.2. Monitoring results of power frequency electromagnetic field in spring and summer.

SEM-600 electromagnetic environment monitoring instrument and LF-01 electromagnetic field probe produced by Beijing Safety Test Technology Co., Ltd is used for power frequency electromagnetic field measurement. The range of electric field is 0.5V/m~100kV/m, the accuracy is 0.01V/m, the range of magnetic induction intensity is 10nT~3mT, the accuracy is 1nT, and the operating temperature is -10~60°C. The electromagnetic field probe is 1.5m away from the ground. Five groups of values are measured at each monitoring point. The results are averaged.

![Figure 5. Distribution of power frequency electric field along vertical lines in spring and summer.](image)

Comparing the measurement results in spring and summer, the trend of power frequency electric field along the measurement path is shown in Figure 5. The variation trend of power frequency magnetic induction intensity along the measurement path is shown in Figure 6.

From the distribution of power frequency electromagnetic field in spring and summer, it can be seen that:
(1) The influence of UHV DC lines on power frequency electromagnetic environment is not obvious law.

(2) Because of the high load and high temperature of high voltage AC lines in summer, the sag of transmission line is low. The maximum of power frequency electric field intensity is 7.04 kV/m in summer and 5.08 kV/m in spring, it is 38.5% higher in summer than in spring.

(3) Whether in spring or summer, the values of power frequency magnetic induction intensity are on the small side, and the contrast change is not obvious. It accords with the theoretical rule. The maximum value is only 2.79μT, which is only 2.79% of the national standard (100μT).

(4) The power frequency electromagnetic field intensity at 0-30m shows an increasing trend, which is mainly affected by the 220 kV AC transmission lines on the West side.

5. Conclusions

(1) The maximum value of composite field strength is 5.8 kV/m in positive polarity and 20.15 kV/m in negative polarity, which meets the 30 kV/m limit of cultivated land under transmission lines stipulated by national standards of China and the United States. [2,11]

Wind will have a greater impact on the DC composite field strength. Monitoring the DC composite field strength should be carried out in windless or breezy weather as far as possible.

(2) The maximum of power frequency electric field intensity is 7.04 kV/m in summer and 5.08 kV/m in spring, and the maximum value of power frequency magnetic induction intensity is only 2.79μT, which all meet the national standard limits of 10 kV/m and 100μT for cultivated land under transmission lines[12]. The standard limits of many countries are summarized by International Council on Large Electric systems. The maximum electric field intensity limit under the line is 10~15kV/m. Limit value of power frequency magnetic induction intensity of IEEE and ICNIRP is 100 μT[2,12,13,14].

(3) AC transmission lines may have some influence on DC composite field strength, which needs further study.

(4) The influence of UHV DC line on power frequency electromagnetic field is small, and the power frequency electromagnetic field is mainly affected by distance and wire height to the ground.
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