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Environmental Impact Assessment and Control Technologies for Electromagnetic Fields in High Voltage AC Transmission Lines

Rina Su[1,✉], Yunfeng Yan[1], Fei Hao[1], Hao Sun[1], Peng Chen[1], Tianlong Zhang[1]

[1] *Inner Mongolia Power Group Wuhai Extra High Voltage Power Supply Company, Wuhai, Inner Mongolia, 016000, China*

ABSTRACT

The load of power supply has been increasing in recent years, and the scale of the power grid has been expanding. The impact of electromagnetic radiation on the lives of residents is also increasingly visible, and the electromagnetic environment around high-voltage AC transmission equipment has attracted great attention. Based on the principle of electromagnetic induction and Gauss theorem, this paper proposes the calculation method of electromagnetic radiation to evaluate the distribution law of spatial electromagnetic field around high-voltage AC transmission lines. Then the risk analysis of the electromagnetic environment around the high-voltage AC transmission line is carried out from the height from the ground and the presence of woods according to the measured data. Finally, according to the electromagnetic law of high-voltage transmission lines, the safety control technology to reduce the environmental impact of electromagnetic fields is proposed, mainly by raising the vertical height of the arc of the transmission line from the ground and reasonably designing the distribution of forest planting in the vicinity of the transmission line. When the vertical height of the conductor's arc height from the ground was increased from 10m to 40m, the electric field strength and magnetic induction strength were reduced by 2.9kV/m and 2.35μT correspondingly, and at the same time, the electric field strength in the vicinity of the building was reduced by 71% at the most. The study proposes measures to effectively mitigate the electromagnetic impact by reasonably analysing the electromagnetic environment in the area where the UHV transmission line is located.

Keywords: Electromagnetic induction principle, Gauss theorem, Electromagnetic field environment, High-voltage AC transmission line, Safety control technology

1. Introduction

The continuous development of power systems and the increasing number of high-voltage transmission lines have led to increasing concern about electromagnetic interference in power

✉ Corresponding author.
E-mail address: bj2008_zl@163.com (R. Su).

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systems and electromagnetic environmental problems. High-voltage transmission lines may cross the scope of residential activities, and may even have an impact on public life in urban areas. As electromagnetic fields and invisible and intangible, at the same time, electromagnetic fields will also be affected by the surrounding environment, including buildings, animals and plants, etc., different changes, so it is often difficult to judge the degree of harm caused by it to people [1-2].

With the increase of public awareness of ecological and environmental protection, the pressure on the State Grid Corporation (SGC) to cope with the problem of industrial frequency electric field complaints has been increasing, and the requirements for the SGC's electric field monitoring capability have also been raised from uniform electric field measurements in the open area to non-uniform electric field measurements in the narrow space [3-6]. At present, there are many ways of electric field measurement on the market, of which the two main categories are electrical and optical. One of the working principle of the electrical electric field measurement sensor is mainly the electric field on its field conductor role so that the conductor induced current or voltage, the current or voltage through the subsequent amplification circuit to amplify the signal, the amplified value after a series of calculations to get the electric field strength conversion value [7-11]. The working principle of the optical electric field measurement sensor is mainly to use the optical effect to change the shape of the photosensitive components or electrical parameters, through the calculation and analysis of the size of the degree of change converted into the corresponding electric field [12-14].

Tarko, R. et al. proposed a method for changing the design parameters of power lines and determining the spatial distribution of conductors, and used a computational model to determine the electric field and audible noise in the environment of the power lines, analysing the possibility of this method to reduce the width of the zone of influence of the electric field [15]. Gao, S. et al. studied the impact of power transmission and transformation projects on electromagnetic radiation in the surrounding environment, based on the monitoring and analysis of various data from the transmission and transformation system of substation equipment, it was found that the electric field intensity was highest in the vicinity of the circuit breaker, and the main concentration area of noise was near the reactor [16]. Ande, J. R. P. K. et al. used EMI modelling, simulation and grid stability assessment methods to analyse the impact of EMI on the grid performance of power distribution grids with the aim of reducing the impact of EMI on high-voltage transmission lines through design, planning and operational procedures to safeguard the needs of users [17]. Buyakova, N. V. et al. examined the electromagnetic pollution of high-voltage transmission lines with different spatial distribution of conductors, and the results of the experiments showed that the spatial arrangement of the conductors significantly affects the maximum magnitude of the electric and magnetic fields, and the maximum magnitude of the electric field is generated when the conductors are positioned at the corners of the triangles [18]. Chervenkov, A. G. analysed the impact of electric fields generated by high-voltage bookstore lines in highly urbanised environments on newly constructed dwellings, constructing Poisson's equation-based magnetic field models to assess the level of electric and magnetic fields in the building area to ensure the health of the inhabitants under the permissible criteria for public exposure [19]. Tang, G. Combined with the specifics of electric field distortion, the safety warning distances for human beings in the vicinity of different types of high-voltage transmission lines are calculated based on the electric field strength limits to prevent safety accidents from occurring [20]. Yordanova, M. et al. developed a computer programme based on the mirror method, which is able to calculate the strength of the electric field at any location under a power line and in this way to assess the risk of exposure of the human body to electric fields [21]. Chervenkov, A. G. constructed a computational model of electromagnetic fields in overhead high-voltage lines and performed analytical calculations and numerical simulations of magnetic fields in high-voltage power lines in the normal mode, short-circuit mode, and lightning-strike mode to assess the effects of exposure to electromagnetic fields on the human body [22].

The paper first briefly describes the generation and measurement principle of electric field, regards the alternating voltage and current in the power system as electrostatic field, and makes use of the static field theory in the theory of electromagnetic wave and electromagnetic field to carry out the relevant calculation of electromagnetic radiation in the power system. Based on the field measurements of electromagnetic environment of high-voltage AC transmission lines, the spatial electromagnetic field distribution law of high-voltage AC transmission lines is explored. Then, the safety assessment of the electromagnetic environment of high-voltage transmission lines is carried out in terms of occupational exposure limits and public exposure limits. Finally, it is proposed to adopt the methods of raising the vertical height of the wire arcs of transmission lines from the ground and reasonable tree planting to reduce the impact of electromagnetic fields on the environment, and the feasibility of the method is examined.

2. Measurements of the electromagnetic environment in electromagnetic fields

2.1. Definitions related to electromagnetic environment measurements in power systems

In China, the voltage level of transmission lines is generally 10kV, 35kV, 66kV, 110kV, 220kV, 500kV, 800kV, 1000kV and so on. According to its current characteristics, there are AC transmission lines (industrial frequency 50Hz) and DC transmission lines. High-voltage AC transmission lines and high-voltage transmission equipment have the following two characteristics:
1) high voltage, in order to be able to reduce the power in the transmission process of line loss, usually taken to increase the voltage to reduce the current way, high-voltage transmission lines operating voltage is generally in kV units.
2) Low frequency, 50Hz (industrial frequency) in the electromagnetic spectrum belongs to the very low frequency, compared with radio and television, microwave communications to be 5 to 10 orders of magnitude smaller. Therefore, the industrial frequency electromagnetic field can be regarded as static field.

Transmission lines in operation in the surrounding space will produce an electric field, because of its extremely low frequency can be regarded as a static electric field has the universal characteristics of the static electric field:
1) The strength of the electric field is proportional to the voltage on the wire.
2) In the electric field in the conductive body (such as buildings, trees, etc.) will make the electric field serious distortion, thus producing a certain shielding effect.

Usually the electric field in nature is very weak, due to the high voltage transmission line voltage level is relatively high so the high voltage transmission line of the electric field generated by the intensity of the electric field than the natural world and the daily environment of the electric field is much larger.

High-voltage AC transmission lines are composed of three-phase conductors, three-phase conductors in the voltage amplitude size is equal, the phase difference of 120 °, so high-voltage transmission lines near the size and distribution of the ground field strength and the form of conductor arrangement: three-phase conductor horizontal distribution of the field strength and the scope of influence of the largest, followed by the triangular arrangement, the inverted triangular arrangement when the smallest.

When the high-voltage transmission lines in the current through the magnetic field will be generated in the surrounding. Magnetic field has some different characteristics with the electric field.

2.2. Principles of Electric Field Generation and Measurement

In the nineteenth century, the electromagnetic field theory was born, in 1831, Faraday discovered the law of electromagnetic induction, in 1865, Maxwell established the famous mcthinking electromagnetic field equations, from then on, mankind's understanding of the electromagnetic phenomenon and the application of an unprecedented height.

Coulomb's law [23]:

$$\vec{F}_{21} = k\frac{q_1 q_2}{r_{21}^2}\vec{e}_{r_{21}} = -\vec{F}_{12} \tag{1}$$

$$k = 8.9880\times10^9\, Nm^2C^2 \tag{2}$$

Introducing the vacuum dielectric constant ε_0, let $k = \dfrac{1}{4\pi\varepsilon_0}$:

$$\varepsilon_0 = \frac{1}{4\pi k} = 8.85\times10^{-12}\, C^2/N\cdot m^2 \tag{3}$$

$$\vec{F}_{21} = \frac{q_1 q_2}{4\pi\varepsilon_0 r_{21}^2}\vec{e}_{r_{21}} = -\vec{F}_{12} \tag{4}$$

The electric field strength at a point in an electric field is a vector quantity whose direction is the direction of the force on a positive test charge and is numerically equal to the electric field force on a unit charge at that point:

$$\vec{E} = \frac{\vec{F}}{q_0} \tag{5}$$

Where: $\vec{E}$ is the electric field strength.

$\vec{F}$ is the electric field force on the test charge.

q_0 is the charge of the test charge (probe charge) placed at a point in the electric field.

The electric field strength obeys the principle of increasing field strength, i.e., the total field strength in space is equal to the vector sum of the field strengths of each electric field when it exists alone:

$$\vec{E} = \sum_i \vec{E}_i \tag{6}$$

Where: $\vec{E}_i$ is the electric field strength at the field point when the ind charge in the point charge system is alone.

High-voltage alternating current transmission lines generated by the industrial frequency electric field refers to the electric field generated by the power at any time for the frequency of 50Hz cycle change, the measurement method refers to the following relevant norms and standards. High-voltage alternating current overhead transmission lines and substations. Measurement Methods of Industrial Frequency Electric Field and Magnetic Field", 'Guidelines for the Management of Radiation Environmental Protection - Electromagnetic Radiation Monitoring Instruments and Methods', 'Technical Specification for Monitoring of Electromagnetic Environment in Power Transmission and Transformation Engineering'. Technical Specification for Electromagnetic Environmental Monitoring in Engineering", 'Technical Specification for Labor Environmental Monitoring in Electric Power Industry Part 7: Monitoring of Industrial Frequency Electric and Magnetic Fields', 'Measurement of Physical Factors in Workplaces Part 3: Industrial Frequency Electric Fields'.

Spherical dipole field strength meter is a suspended body type field strength meter, the measurement is very accurate, for the International Conference on Large Power Grids Working Group No. 36.01 one of the recommended instruments for measuring the field strength of the industrial frequency, it is measured on the working principle of the current in the meter is proportional to the strength of the measured electric field, the scale of the ammeter is labeled into the scale of the electric field strength.

The detection electrode of the field strength meter is a dipole composed of two hemispheres, which are insulated from each other along the equatorial plane and connected to a low-impedance measurement circuit. The dipole electrode is put into the industrial frequency electric field, the induced current produces a voltage drop at the input of the measuring circuit, which is amplified and rectified by the measuring circuit and sent to the meter head for display, and the electric field strength of the measured electric field can be read out directly:

$$I = \frac{dQ}{dt} = kw_0 E_0 \cos wt \tag{7}$$

Where: k is a parameter related to the condition of the probe pole plate, which can be obtained by calibration.

E_0 is the electric field strength to be measured.

w is the electric field angular frequency.

At present, environmental protection monitoring in the use of industrial frequency field strength monitoring instruments are basically used in the above principle of development and production.

2.3. Calculations related to electromagnetic radiation in power systems

Because the alternating voltages and currents in the power system are very low frequency (50Hz), they can be regarded as electrostatic fields. Therefore, in the power system in the relevant calculations can be used in electromagnetic waves and electromagnetic field theory of static field theory processing.

In order to calculate the maximum value of the ground electric field strength, usually to the maximum arc of the line at the (minimum height to ground) when the full load is calculated. Considering that the equivalent charge Q in each wire is known, the electric field strength at any point $P(x,y)$ in space can be calculated according to Gauss' theorem and the principle of superposition [24]:

$$E_{i1} = \frac{Q_i}{2\pi\varepsilon\sqrt{(x_i - x)^2 + (y_i - y)^2}} \tag{8}$$

where x_i and y_i are the horizontal and vertical coordinates of wire i, respectively.

The mirror charge $-Q$ of wire i produces an electric field strength at point $P(x,y)$:

$$E_{i2} = \frac{-Q_i}{2\pi\varepsilon\sqrt{(x_i - x)^2 + (y_i + y)^2}} \tag{9}$$

Then the electric field strength generated by wire i and its mirror wire at point $P(x,y)$ is collectively:

$$E_i = \frac{Q_i}{2\pi\varepsilon}\left(\frac{1}{\sqrt{(x_1 - x)^2 + (y_i - y)^2}} - \frac{1}{\sqrt{(x_1 - x)^2 + (y_1 + y)^2}}\right)\cdots \tag{10}$$

According to the principle of superposition, the electric field strength components Ex and Ey generated by m wire at point $P(x,y)$ are expressed as:

$$E_x = \frac{1}{2\pi\varepsilon}\sum_{i=1}^{m} Q_i\left(\frac{x - x_i}{\sqrt{(x_1 - x)^2 + (y_1 - y)^2}} - \frac{x - x_i}{\sqrt{(x_1 - x)^2 + (y_1 + y)^2}}\right)\cdots \tag{11}$$

$$E_y = \frac{1}{2\pi\varepsilon}\sum_{i=1}^{m} Q_i\left(\frac{y - y_i}{\sqrt{(x_1 - x)^2 + (y_1 - y)^2}} - \frac{y - y_1}{\sqrt{(x_1 - x)^2 + (y_1 + y)^2}}\right)\cdots \tag{12}$$

Due to the quasi-static nature of the electromagnetic properties in the industrial frequency case, the magnetic field of the line is generated only by the current. By applying Ampere's law and superimposing the results of the calculations by vectors, the strength of the magnetic field around the conductor can be derived. In general, only the actual conductor is considered ignoring its mirror image for the calculation, and the results are sufficiently realistic. The result is shown in Figure 1, without considering the mirror image of wire i, can be calculated which A points generated by the magnetic field strength, expressed by the formula (13):

$$H = \frac{1}{2\pi\sqrt{h^2 + L^2}} \tag{13}$$

Where H indicates the strength of the magnetic field generated at point A, I indicates the current in wire i, h indicates the height of wire erection, and L indicates the horizontal distance between any point and the wire. In order to comply with the unit specification, the actual application is converted to magnetic induction strength $B(mT)$ said.

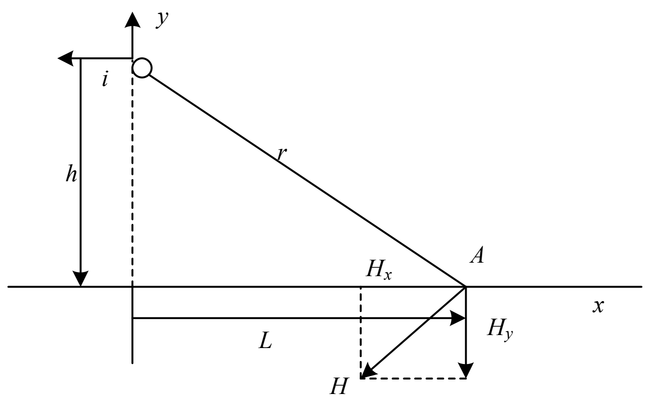

Fig. 1. Calculation of field strength

For three-phase circuits, both the horizontal and vertical components of the magnetic field strength formed by different phases must be synthesised as phase vectors by considering the phase angle between the currents separately.

2.4. Practical measurements of the electromagnetic environment

Setting of monitoring points: According to the environmental protection industry standard of the People's Republic of China, 'Radiation Environmental Protection Guidelines - Electromagnetic Radiation Monitoring Instruments and Methods' in the environmental measurement layout requirements, and at the same time, according to the actual situation of the environment around the substation and the line, the monitoring points can be arranged in 8 directions around the substation.

Instruments used: The monitoring uses the EFA-300 low-frequency electromagnetic radiation analyser of German Narda company [25]. Used for low-frequency electromagnetic field measurements, such as high-voltage transmission lines, substations, distribution rooms, induction furnace, underground, tram and other places of operation or public places, for the study of low-frequency electromagnetic radiation of the equipment or environmental low-frequency electromagnetic radiation measurements or research in different fields. Main features:

1) The world's current optimal performance of the integrated electromagnetic field measurement system
2) 5Hz-32KHz, 30Hz-32KHz, 5Hz-2KHz, 30Hz-2KHz broadband to meet the different needs of the measurement, the natural background comparison measurement
3) Three-dimensional isotropic measurement probe (non-directional)
4) 0.7v/m-100Kv/m large dynamic electric field measurement range
5) 4nT-32mT large dynamic magnetic field measurement range

6) Active identification of the source frequency, can be selected frequency measurement
7) RS-232 interface fibre optic data transmission
8) Optional spectrum analysis / harmonic analysis function module
9) Any strong field can be automatically adjusted to zero high-precision measurement
10) Dustproof, shockproof, easy to use

Monitoring conditions: Measurement of substation substation equipment and transmission lines must reach the rated voltage and under full load, substation electrical equipment must be in operation. Due to. The monitoring results will be affected by the weather conditions, so it is required that the weather conditions are good during the monitoring, and the measurement is prohibited under cloudy and rainy weather.

The electromagnetic environment of the HVAC transmission line is assessed by analysing the results of the actual monitoring.

3. Dimensionless processing of data

3.1. Several definitions in data processing

Original measured value - the original, unprocessed, unprocessed value of the field strength of the high voltage AC transmission line measured in the field.

Normalised measured value - the value after normalisation of the original measured value of the industrial frequency electric field strength of the high voltage AC transmission line.

Calculated value - according to the specific operating parameters of the high-voltage AC transmission line, calculated by the calculation software to calculate the value of the industrial frequency electric field strength.

Measured value referred to in this paper for the normalised measured value.

3.2. Normalisation of measured data

The calculation procedure of electromagnetic environmental parameters of AC high-voltage transmission lines used in this study can only select a fixed integer value of the voltage value, while the operating voltage of the high-voltage transmission line operation is a floating change, this study of a voltage level transmission line monthly on the ground below the line of the ground frequency electric field strength of the measurement of the operating voltage, the operating voltage is higher than the value of the voltage level of 3-5%. Therefore, in the case of high-voltage transmission lines. Comparative analysis of the IEF calculation and measured values should be carried out before the original measured value of the normalisation process, and the calculated value of the same voltage parameters under the normalised measured value, and then compared with the calculated value to ensure the reliability of the comparative analysis. According to $E=U/d$, the following normalisation method can be used:

$$Normalized\ measured\ values = Original\ measured\ value \times \frac{Calculated\ Voltage}{Running\ voltage\ value} \tag{14}$$

4. Electromagnetic environment measurements on high-voltage AC transmission lines

4.1. Spatial electromagnetic field distribution of high-voltage AC transmission lines

In order to study the spatial electromagnetic field distribution underneath the high-voltage transmission line, this paper takes the centre line as the centre and the left side as positive, with 0 representing the centre conductor directly underneath. The electromagnetic field strength within 80m to the left of the centre line and the centre line at the height of the probe from the ground of 1.5m was measured. The measured data were plotted and the distribution of electric field strength below the transmission line is shown in Figure 2. As the distance from the centre line is getting farther and farther, the electric field strength increases and then decreases, the maximum value of the electric field strength appears near about 50m from the centre line, and the maximum value is 7.466kV/m, after that, as the distance from the sideline is getting farther and farther, the electric field strength gradually decreases, the sideline is about 50m from the centre line, and about 30m from the sideline, the electric field strength attenuates to 3.0876 kV/m, compared with the maximum value of 7.466 kV/m, the attenuation is 58.6%. The variation of magnetic induction strength under the transmission line is shown in Fig. 3. As can be seen from Fig. 3, the magnetic induction strength first increases and then decreases as the distance from the centre conductor becomes further and further away. The maximum value of the magnetic induction intensity is 2.5844μT, after that, the magnetic induction intensity gradually decreases as the distance from the central conductor gets further and further, the sideline is 20m away from the central conductor, and at about 60m away from the sideline, the magnetic induction intensity is attenuated to 0.802μT, which is 68.27% attenuation compared to the maximum value of 2.5844μT.

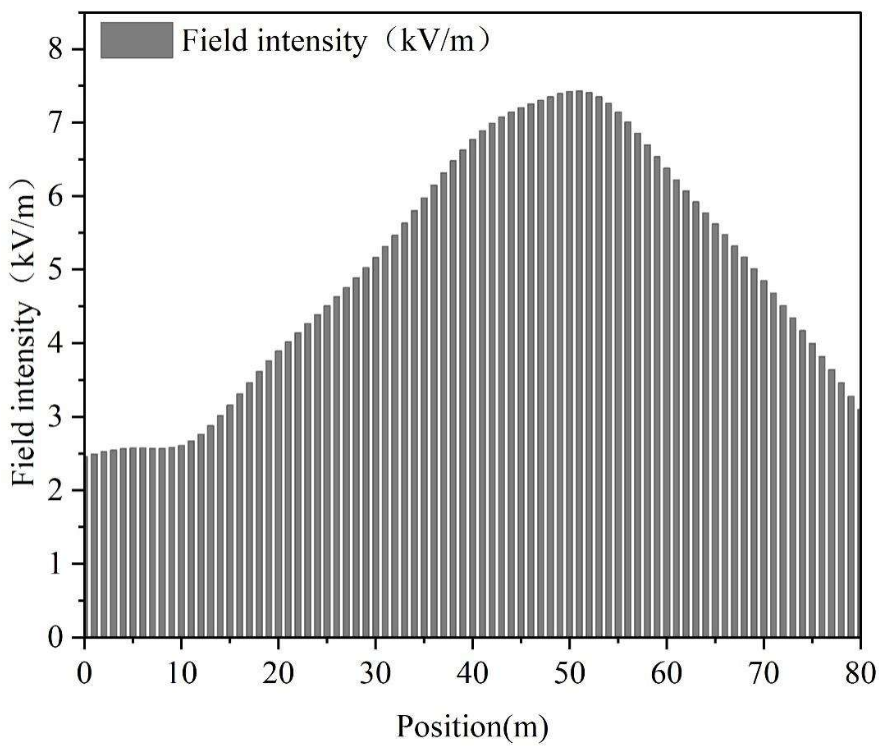

Fig. 2. The field intensity distribution under the transmission line

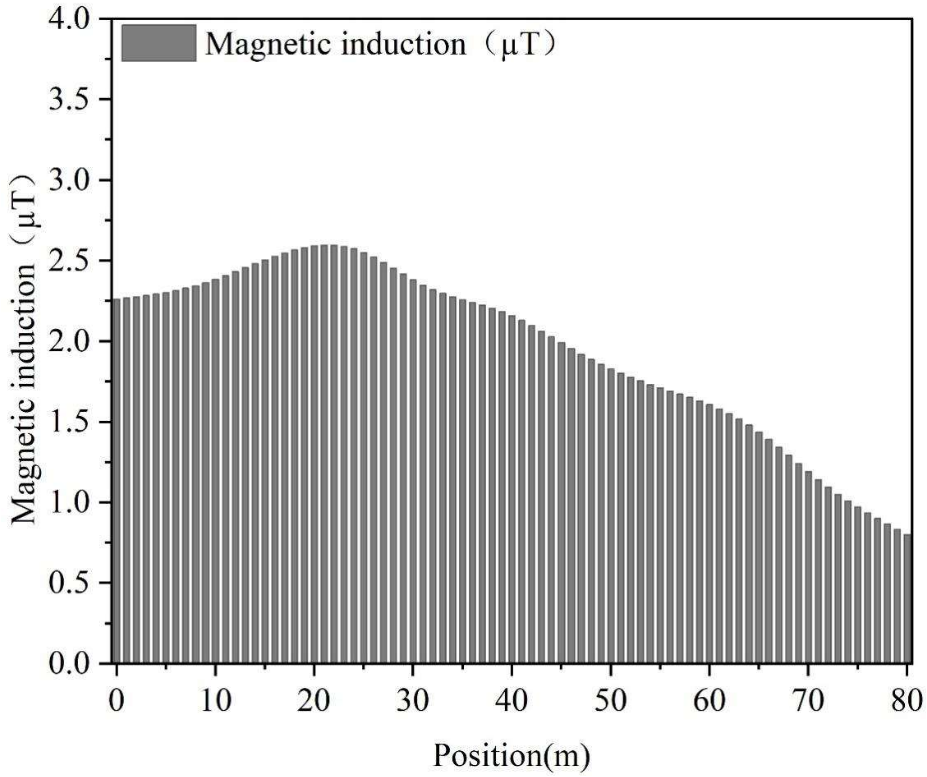

Fig. 3. The magnetic induction intensity changes under the transmission line

4.2. Effect of height above ground on the electromagnetic environment

In order to study the effect of height from the ground on the electromagnetic environment of 1000kV high-voltage transmission lines, this paper takes the centre line as the centre, and measures the electric field intensity and magnetic induction intensity in the left and right sides at 20m from the centre line respectively. Selected height from the ground were 50cm, 100cm, 150cm. will measure the data plot, the height of the electric field strength of the influence of the graph in Figure 4. As shown in Figure 4, the probe height from the ground for 50cm, 100cm, 150cm, the electric field strength of the minimum value of the central conductor directly under the two with the distance from the centre of the conductor position is getting farther and farther, the electric field strength is a tendency to rise. Probe height from the ground for 50cm and 100cm, the electric field strength are less than the electric field strength at 150cm. The influence of height on the magnetic induction intensity is shown in Figure 5, the minimum value of the magnetic induction intensity when the height of the probe from the ground is 50cm, 100cm and 150cm is directly below the centre wire, and the magnetic induction intensity tends to increase as the distance from the centre wire becomes further and further away. Probe height from the ground for 50cm, 100cm and 150cm of the magnetic induction intensity of the two circuits centre as the axis of symmetry of the left and right sides of the basic symmetrical distribution.

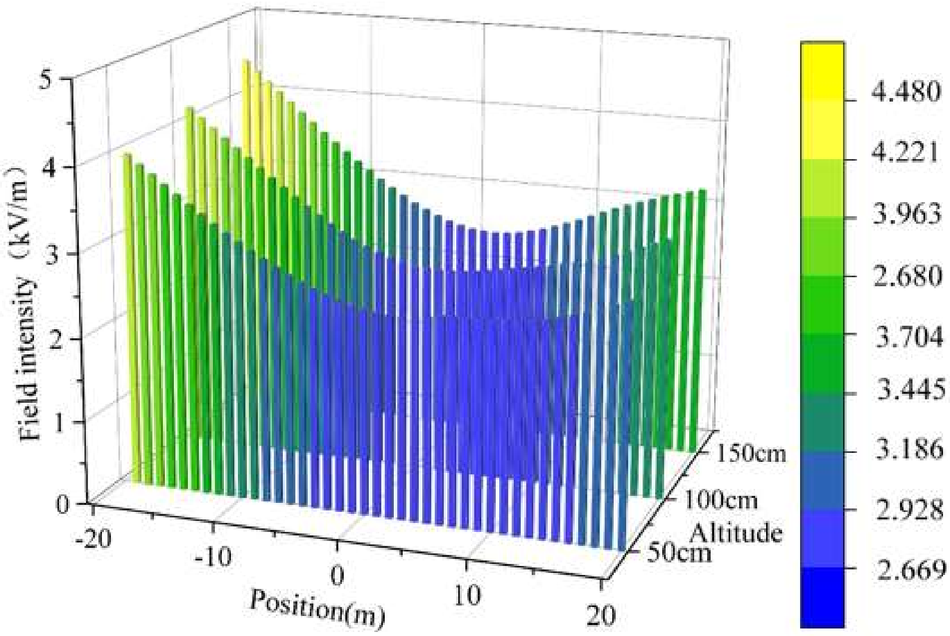

Fig. 4. The effect of altitude on electromagnetic field intensity

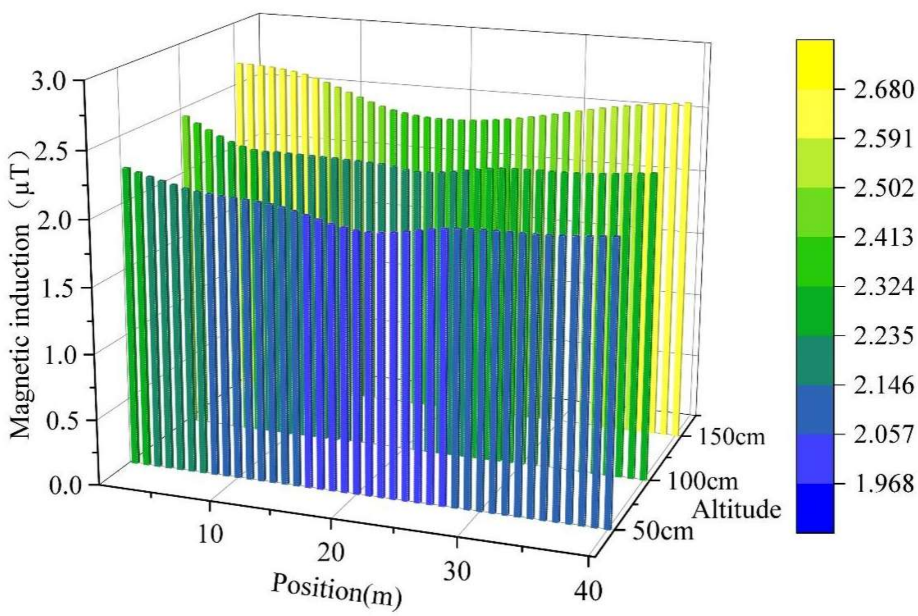

Fig. 5. The effect of height on magnetic induction intensity

4.3. Impact of woods on the electromagnetic environment

In order to study the influence of the woods on the high-voltage 1000kV electromagnetic environment, the values of electric field strength and magnetic induction strength were measured when the probe was at a height of 1.5m from the ground, and the probe was in the woods at 15m, outside the woods at 3m, and outside the woods at 13m, respectively. The measurement results are shown in Table 1. Where positive numbers represent outside the woods and negative numbers represent inside the woods. Where -15m means that the probe is placed 15m in the woods, 3m means that the probe is placed 3m outside the woods, and 13m means that the probe is placed 13m outside the woods. during the process of moving the probe from the woods to 15m outside the woods, the E-field strength tends to increase, and the E-field strength of the probe is 0.0259kV/m when it is placed at 15m in the woods, and the value of the E-field strength of the probe when it is moved to 15m outside the woods is 3.5469kV/m, the electric field intensity at 15m outside the woods is 137 times of that at 15m in the woods, which shows that the woods have a greater influence on the electric field. During the process of moving the probe from the woods to 15m outside of the woods, the magnetic induction strength shows an increasing trend, we put the probe at 15m in the woods, the magnetic induction strength is 2.2101 μT, we move the probe to 15m outside of the woods, the magnetic induction strength is 2.2357 μT, the magnetic induction strength 15m outside of the woods is 1.01 times of that of the 15m in the woods, and the results show that the woods have a smaller influence on the magnetic field The results show that the woods have less influence on the magnetic field.

Table 1. The forest is affecting the variation of electromagnetic field intensity

Position (m)	Field intensity (kV/m)	Magnetic induction (μT)
-15	0.0259	2.2101
3	1.2106	2.2208
15	3.5469	2.2357

4.4. Safety assessment of the electromagnetic environment of high-voltage transmission lines

1) Comparison of parawood measurements with ICNIRP standards. Comparison with ICNIRP occupational exposure limits. The data measured near the woods below the high-voltage transmission line were collated, and the measured maximum values were compared with the ICNIRP occupational electromagnetic exposure standard limits, and the comparison results are shown in Table 2. The measured value of magnetic induction strength is 0.22% of the ICNIRP standard occupational exposure limit, and the field measured value of electric field strength is 37.4% of the ICNIRP standard occupational exposure limit. The electric field strength and magnetic induction strength are less than the ICNIRP standard occupational exposure limits.

Table 2. Comparison of forest measurement with occupational exposure

Field type	Measured maximum	Icnirp standard occupational exposure limit	The measured proportion is the standard proportion
Field intensity (kV/m)	3.7515	10	37.51%
Magnetic induction(μT)	2.2645	1000	0.22%

Comparison with ICNIRP standard public exposure limits. Measurement data at different heights below the high-voltage transmission lines were collated, and the measured maximum values were compared with the ICNIRP standard limits for public electromagnetic exposure, and the comparison results are shown in Table 3. The measured value of magnetic induction strength is 1.13% of the ICNIRP standard public exposure limit, and the field measured value of electric field strength is 75.03% of the ICNIRP standard public exposure limit. The electric field strength and magnetic induction strength are less than the ICNIRP standard public exposure limit.

Table 3. Different height measurements are compared to the standard audience

Field type	Measured maximum	Icnirp standard occupational exposure limit	The measured proportion is the standard proportion
Field intensity (kV/m)	3.7515	5	75.03%
Magnetic induction (μT)	2.2645	200	1.13%

2) Comparison of the measurement results of 1.5m cross-section below the conductor from the ground with

ICNIRP standard. Comparison with ICNIRP standard occupational exposure limits. The measurement data of 1.5m cross-section from the ground underneath the high-voltage transmission line is collated, and the measured maximum value is compared with the ICNIRP standard limit value of occupational electromagnetic exposure, and the comparison results are shown in Table 4. The measured value of magnetic induction strength is 0.26% of the ICNIRP standard occupational exposure limit, and the field measured value of electric field strength is 75.7% of the ICNIRP standard occupational exposure limit. The electric field strength and magnetic induction strength are less than the ICNIRP standard occupational exposure limits.

Table 4. Different height measurements are compared to occupational exposure

Field type	Measured maximum	Icnirp standard occupational exposure limit	The measured proportion is the standard proportion
Field intensity (kV/m)	7.547	10	75.70%
Magnetic induction (μT)	2.5769	1000	0.26%

Comparison with ICNIRP standard public exposure limits, the measurement data of 1.5m cross-section from the ground underneath the high-voltage transmission line were collated, and the maximum value of the measurement was compared with the ICNIRP standard public electromagnetic exposure limits, and the comparison results are shown in Table 5. The measured value of magnetic induction strength is 1.29 per cent of the ICNIRP standard public exposure limit, and the field measured value of electric field strength is 150.94 per cent of the ICNIRP standard public exposure limit.

Table 5. Different height measurements and audience exposure limits

Field type	Measured maximum	Icnirp standard occupational exposure limit	The measured proportion is the standard proportion
Field intensity (kV/m)	7.547	5	150.94%
Magnetic induction (μT)	2.5769	200	1.29%

5. Control measures to mitigate electromagnetic effects

5.1. Raising the vertical height of transmission line conductor arcs from the ground

According to the “electromagnetic environment attenuation law analysis” of transmission lines in the vertical direction of the industrial frequency electric field intensity, magnetic induction intensity, radio interference value with the height of the overhead line increases and decreases. The design can be used to raise the vertical height of the line conductor arc from the ground in order to reduce the impact of electromagnetic environment. Specific prediction point height design for 1.5m, through the specific prediction point of the same conditions of different line height comparison calculation, calculation if shown in Figure 6, with the vertical height of the wire arc from the ground to lift the prediction point of the frequency electric field intensity, magnetic induction intensity are reduced significantly, when the vertical height of the wire arc from the ground from 10m to 40m, the electric field intensity reduced by 2.9kV / m, magnetic induction intensity reduced by 2.35μT. Therefore, the method of raising the vertical height of the wire arc from the ground in order to reduce the electromagnetic environmental impact is effective and can be used to control the electromagnetic environmental impact of high-voltage AC transmission lines.

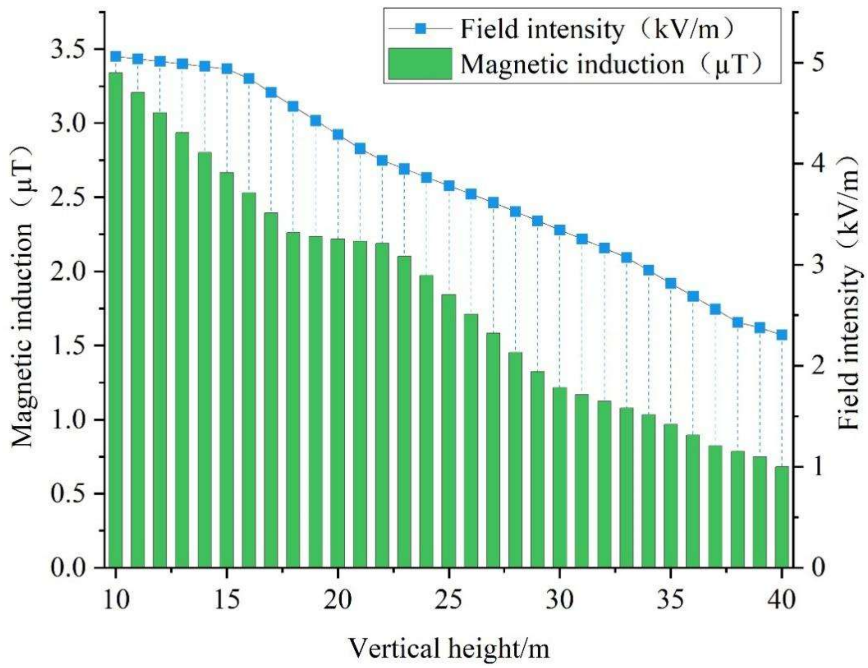

Fig. 6. The line conductor is compared to the different vertical altimeter

5.2. *Rationalising the distribution of woodland planting*

Shielding is one of the effective methods of suppressing electromagnetic nuisance widely used in electromagnetic compatibility engineering. The so-called shielding is to use the shielding body to limit the source of electromagnetic harassment in a certain range so that the source of harassment from the shielding body of one side of the coupling or when it is radiated to the other side of the inhibition or attenuation, 4.3 of the analysis results found that the existence of the woods on the electromagnetic harassment of the incident electric field has a certain degree of shielding effect. Therefore, the method of reasonable tree planting is adopted to shield electromagnetic harassment.

After the reasonable setting of tree planting distribution, the electric field strength of an electric field changes as shown in Figure 7. In the transmission line below the planting of certain trees and plants, the line below the industrial frequency electric field strength reduction is obvious, the maximum can be reduced around the top of the building set up a metal grounding fence after the iron frame on the inside of the field shielding effect is better at the same time, while the edge of the roof of the building and the corners of the field to reduce the strength of the maximum can be reduced by 71%. Therefore, the use of reasonable tree planting method to reduce the intensity of local industrial frequency electric field effect is obvious.

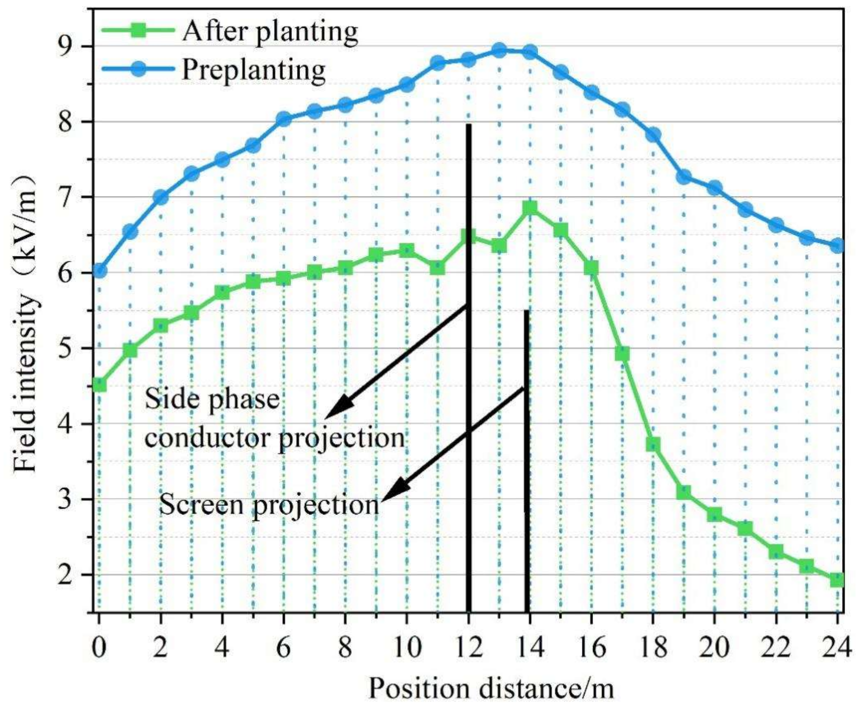

Fig. 7. Contrast of field intensity after planting of trees

6. Conclusion

Combines the electromagnetic environment calculation method of high-voltage AC transmission lines with practical examples. The electromagnetic environmental impact of the area where the high-voltage transmission line is located is assessed, and measures to effectively mitigate the electromagnetic impact are proposed. The main conclusions are as follows.

When the height of the prediction point is designed as 1.5m, with the vertical height of the conductor's arc plumbing from the ground rising, the industrial frequency electric field intensity and magnetic induction intensity at the prediction point are reduced accordingly, and when the vertical height of the conductor's arc plumbing from the ground is increased from 10m to 40m, the electric field intensity and magnetic induction intensity are reduced by 2.9kV/m and 2.35μT respectively, which indicates that the electromagnetic environmental impacts can be reduced by elevating the vertical height of the conductor's arc plumbing from the ground of the transmission line. Reduce the electromagnetic environmental impact.

After the reasonable setting of tree planting distribution, the electric field intensity change curve is shifted downward as a whole. It shows that after tree planting, the intensity of industrial frequency electric field below the line is reduced as a whole, and it can be reduced at most by the metal grounding fence erected on the top of the left and right buildings after the iron frame. The field strength shielding effect on its interior is better, while the field strength at the edges and corners of the roof of the building can be reduced by a maximum of 71%. Therefore, the use of trees reasonable planting method to reduce the local industrial frequency electric field strength effect is significant.

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