Analysis on Electromagnetic Environment from 750 kV Transformer Substation in Gansu Power Network

Shigang Gao¹*, Guohua Chang², Honggang Chen¹ and Wei Li¹

¹Electric Power Research Institute, State Grid Gansu Electric Power Company, Lanzhou, Gansu, 730070, China
²College of Geography and Environmental Engineering, Lanzhou City University, Lanzhou City, Gansu, 730070, China
*Corresponding author’s e-mail: goshegun@163.com; cgh@lzcu.edu.cn

Abstract. In order to understand the influence of 750 kV power transmission and transformation project on electromagnetic radiation of surrounding environment, the data of electric field intensity, magnetic field intensity and noise from 750 kV substation equipment transmission and transformation system in some areas of Gansu Province were monitored and analyzed. The results showed that the areas near circuit breaker, switch and reactance in the power transmission system were the main areas producing high electric field intensity. The electric field intensity near the circuit breaker is the highest in substation equipment, with the average value of 12.40 ± 1.25 kV/m, while the main noise producing area is near the reactor. The study could provide scientific basis for environmental assessment and prevention of ultrahigh voltage power transmission projects.

1. Introduction

Electric energy, as an important way of energy utilization, plays a very important role in the sustainable development of national economy, social and environment. The demand for electricity in people’s production and life has grown rapidly, with the rapid development of China’s economy in recent decades. Total national electricity consumption of China in 1985 was 411.76 billion kilowatt-hour (kwh), while in 1995 and 2005, the total national electricity consumption was 1002.34 and 2494.03 billion kwh, respectively. The values in 2015 and 2019 reached 5802 and 7225.5 billion kwh, respectively [1]. At the same time, the power grid system of China has also been expanding rapidly, and the power grid capacity and the voltage level of transmission lines have also been improving, continuously. With the continuous completion of a large number of power transmission and transformation projects, the health risks that may be brought to the environment and human body have become the focus of many people based on the electromagnetic field and noise generated by power transmission and transformation projects. Therefore, the monitoring and analysis of the electromagnetic environment from the transmission and transformation system in operation and the research on the influence of its surrounding environment are helpful for people to scientifically understand the influence of high-voltage transmission and transformation system on environment and human health. It can also provide a scientific basis for the construction of similar power transmission projects and the implementation of environmental impact assessment as well.
At present, the studies on the influence of electromagnetic radiation from power transmission and transformation projects on environment was mostly conducted for 110 kV, 220 kV and 500 kV projects [2-7], while researches on electromagnetic radiation of 750 kV EHV power transmission and transformation projects has less been concerned [8-10]. The maximum power frequency electric fields of some 110 kV substations in Chengde area were 124.2, 20.6 and 17.3 V/m respectively, which appear at 0, 0 and 20 m away from the substation wall. The maximum vertical component of power frequency magnetic field appears at 0 m away from the wall, which is $2.72 \times 10^{-2} \mu T$ [2]. From 2010 to 2015, 37 sensitive targets from 110 kV transmission and transformation projects and electromagnetic environment in Huzhou area were monitored for power frequency electromagnetic field. The results showed that the maximum power frequency electric field intensity from substations was 0.574 kV/m and the maximum power frequency magnetic induction intensity was 0.846 μT; and the maximum power frequency electric field intensity and magnetic induction intensity from the sensitive targets was 0.400 kV/m and 1.334 μT [3]. Yimingjiang [4] measured the power frequency electromagnetic field from four representative 220 kV substations in Xinjiang, and the results showed that the maximum electric field intensity of the substation was 882.88 kV/m; the maximum magnetic induction intensity was 1.125 μT. The power frequency electromagnetic field intensity of 500 kV substation in Zhangzhou, Fujian was significantly higher than that of 110 kV and 220 kV substations. The maximum electric field intensity was 1285 kV/m, and the maximum magnetic field intensity was 2.754 μT [6]. The monitoring results of high voltage transmission and transformation projects in the above areas were less than the public exposure control limit (power frequency electric field intensity 4 kV/m) specified in GB8702-2014 (Limits of electromagnetic environment control) and power frequency magnetic induction intensity 100 μT [11]. The measurement results of electrical and magnetic field intensity and noise in the surrounding environment of 750 kV substation in eastern Yinchuan showed that the maximum values of electrical and magnetic field intensity were 329.7 V/m and 0.938 μT, respectively, at 10 m outside the substation wall. The noise test value near the high reactance outside the substation wall exceeded the standard [8]. The field strength of 750 kV Lanzhou East Substation was in the range of 1.6 - 7.9 kV/m, and the maximum vertical component of magnetic induction intensity was 1.1 μT, and the maximum horizontal component was 1 μT [9].

In order to further understand the electric and magnetic environment characteristics of 750 kV EHV transmission and transformation projects, we conduct on-site monitoring of the electrical and magnetic field intensity and noise from 750 kV transmission and transformation projects that have been put into operation in Pingliang, Jiuquan, Hexi and other places in Gansu Province. It can provide important reference for the construction and environmental impact assessment of similar power transmission and transformation projects in the future.

2. Measuring Instruments, Power Frequency Electromagnetic Environment Monitoring

In this study, the power frequency electric field, power frequency magnetic field and noise from three 750 kV representative switching stations and substations in Gansu Province were monitored and analyzed, including 82 monitoring points in the switching station. The monitoring points of the other two substations are 181 and 50, respectively. PMM8053 power frequency electromagnetic field tester is used to test power frequency electric field strength and magnetic field.

The test instrument is supported by insulation support, and its center is 1.5 m above the ground, and the tester is not less than 2 m away from the probe, so as to minimize the influence of the human body on the electric field of the measured point. The AWA6270 + type of sound level meter was used to measure the equivalent continuous sound level of each measuring point for 1 min. At the same time, other environmental factors were recorded by anemometer, temperature and humidity meter and air box pressure meter.

The layout of test points for power frequency electric field, power frequency magnetic field and audible noise from 750 kV substation workplaces, staff inspection routes and electrical equipment (switch, breaker, switch, arrester, PT, reactor and main transformer) were mainly around the high voltage live frame of main equipment and along the inspection line. The layout of monitoring points
mainly follows the four points. First, measuring points were 1.5 m away from the outside of vertical projection of the outgoing line interval live frame, and above the ground 1.5 m; Secondly, 1.5 m away from the outside of vertical projection of circuit breaker, and above the ground 1.5 m. Thirdly, 1.5 m away from the vertical projection of the inlet side near the reactor, and above the ground 1.5 m. Forth, on the inspection line, a monitoring point was arranged every 20 meters along the inspection line, and 1.5 m above the ground.

At present, China has issued the technical specification for electromagnetic radiation environmental impact assessment of 500 kV EHV transmission and transformation project (HJ/T 24-1998) [12], Electromagnetic Environment Monitoring Method for AC Transmission and Transformation Project (HJ 681 – 2013) [13] and Measurement of physical factors in workplaces Part 3 : 1 Hz ~ 100 Hz electric and magnetic fields (GBZ/T 189.3-2018) [14] and Limits of electromagnetic environment control (GB8702-2014) [11], in which the evaluation scope, evaluation criteria and measurement methods of power transmission and transformation construction projects were given, and which were also the basis for environmental assessment and acceptance monitoring of power transmission and transformation. The limits of electromagnetic environment control (GB8702-2014) [11] points out that in the electromagnetic field with frequency of 50 Hz (power frequency), the control limit of public exposure is 4 kV/m of power frequency electric field intensity and 100 $\mu$T of power frequency magnetic induction intensity. However, in cultivated land, garden land, pasture land, livestock and poultry breeding land, aquaculture water surface, roads and other places under overhead transmission lines, the control limit of electric field intensity with frequency of 50 Hz is 10 kV/m. the noise at station boundary according to the Environmental Noise Emission Standards for Industrial Enterprises [15] II standard for reference is 60 dB in daytime, and 50 dB at night.

3. Results and discussion

3.1. Formating the title Analysis of electric field, magnetic field intensity and noise variation of 750 kV switch station and substation

The electric field strength, magnetic field strength and equivalent sound level from Pingliang 750 kV switching station in Gansu Province were measured, and the results is shown in Figure 1, and the results of Jiuquan substation and Hexi substation are shown in Figure 2 and 3. It could be seen that the average electric field intensity near the circuit breaker in the monitoring point from Pingliang switch station (Figure 1) was significantly different from that of other measuring points, and the average value was $12.40 \pm 1.25$ kV/m. Secondly, the electric field intensity between reactors and the knife switch was also high. The mean value of electric field intensity measured at open space under the line was the smallest ($4.44 \pm 2.39$ kV/m). Most of the monitoring points were higher than 4 kV/m, and the electric field intensity at line A/B/C phase, between circuit breakers, and circuit breakers were more than 10 kV/m. The magnetic field intensity of each monitoring point was also different. The magnetic field intensity near the circuit breaker was $5.52 \pm 1.28$ $\mu$T, which was significantly higher than that of other points. Compared with other measuring points, the magnetic field intensity at the open space and line A/B/C phase were lower, less than 2$\mu$T. The average noise of each point in the station was mostly more than 60 dB, and the noise near the reactor ($68.07 \pm 3.63$ dB) was significantly higher than that at other points. The equivalent sound level at the line A/B/C phase was the lowest ($59.83 \pm 0.77$ dB).

In each monitoring point of Jiuquan substation, the average electric field intensity near the circuit switch ($6.96 \pm 1.61$ kV/m), circuit switch-knife switch ($7.81 \pm 2.11$ kV/m) and switch-line A/B/CCT inspection path ($8.97 \pm 2.19$ kV/m) were significantly different from that of the I/II line ($2.18 \pm 1.81$ kV/m). A considerable part of the values of monitoring points were higher than 4 kV/m. The magnetic field intensity near the circuit switch was $5.68 \pm 1.19$ $\mu$T, which was significantly higher than that of other points. The average noise of each point in the station was more than 50 dB (Fig. 2).

Among the monitoring points in Hexi Substation, the mean electric field intensity at the I/II line was significantly lower than that of other points which were higher than 4 kV/m. There was no
significant difference between the magnetic field intensity and noise at each monitoring point. The average noise monitored in this substation was between 50 dB and 60 dB.

The significance difference analysis of the mean values of all monitoring points in the above three regions showed that the mean values of magnetic field intensity at Pingliang switching station and Hexi substation were higher than those at Jiuquan substation, and the mean values of electric field intensity measured at these two stations were close to 10 kV/m. The average electric field intensity in the above three regions were all greater than 4 kV/m. The mean value of magnetic field intensity measured at Hexi substation was higher than that of the other two regions. The order of noise mean value from large to small was Pingliang > Jiuquan substation > Hexi substation, and the three noise mean values were all greater than 50 dB, and the noise mean value in Pingliang were more than 60 dB (Fig. 3).

Figure 1. Changes on electric field intensity, magnetic field intensity and equivalent sound from 750 kV switch station in Pingliang.
3.2. Correlation analysis of electric field, magnetic field intensity and noise

In order to understand the relationship between electric field strength, magnetic field strength and equivalent sound level in the above different regions, the correlation analysis of the three factors in the study area was carried out by the SPSS statistics. The results are shown in Table 1. It can be seen that there was a low correlation between electric field intensity and magnetic field intensity in Pingliang.
switching station, and the correlation coefficient was 0.410. Also there was no correlation between electric field intensity and noise. There was also a low correlation between the electric field strength and magnetic field strength measured in Hexi substation and Jiuquan substation. There was no correlation between electric field intensity and noise, and between magnetic field intensity and noise. The electric field intensity and magnetic field intensity in these three regions maintained low correlation, and there was no significant relationship between noise and electric field intensity and magnetic field intensity.

Table 1. Correlation among electric field intensity (EFI), magnetic field intensity (MFI) and equivalent sound level of substation in different areas.

|                  | Pingliang switching station | Jiuquan substation | Hexi substation |
|------------------|-----------------------------|---------------------|-----------------|
| EFI              | MFI                         | Noise               | EFI             | MFI            | Noise           |
| EFI              | 1                           | 1                   | 1               | 1              | 1               |
| MFI              | 0.410**                     | 1                   | 0.447**         | 1              | 0.302**         |
| Noise            | -0.138                      | 0.143               | -0.194**        | -0.043         | -0.204          |
| * Correlation is significant at the 0.05 level (2-tailed). |
| ** Correlation is significant at the 0.01 level (2-tailed). |

High voltage substation is an important facility of high voltage transmission and transformation system. The upper layer of high voltage equipment in the substation has crossed live wires, and the lower layer has various shapes of high voltage live electrical equipment and equipment connection wires. The electrode shape is complex and the number is large. A complex power frequency electromagnetic field is formed in the surrounding space. There are also power frequency electric field and magnetic field near the high voltage switch station [2]. In this study, the monitoring of the switching station area showed that the circuit breaker was the main pollution source, and its electric field strength was more than 10 kV/m. the knife switch and its vicinity were also areas with high electric field intensity. The main source of noise was near the reactor. The switch and its vicinity in substation were places with high electric field intensity. The noise of switching station was obviously higher than that of substation. Compared with the current electric and magnetic field intensities of 110 kV [2, 3, 6], 220 kV [4-6] and 500 kV [5-7] transmission and transformation systems, the average electric and magnetic field intensities of 750 kV transmission and transformation systems were higher than those of the above voltage transmission and transformation systems. Therefore, the higher the voltage level is, the greater its impact on the surrounding electromagnetic environment is, which is consistent with the research results of Li [6].

Li [8] found that the test values of noise at the 750 kV substation in eastern Yinchuan exceeded the standard. The measurement results of Wan et al. [9] in 750 kV Dongguanting Substation in Lanzhou showed that the maximum electric field intensity was 7.9 kV/m under the main transformer. Substation noise source was mainly transformer, the value was 72 ~ 52.3 dB. Therefore, it is necessary to further strengthen the electromagnetic environment monitoring analysis of such transmission and transformation systems in the future. At the same time, it can also provide reference for future project planning and design to reduce its harm and influence.

4. Conclusions
In the switching station and substation of 750 kV high voltage transmission and transformation, the main pollution sources of electric field intensity were circuit breakers, reactors and knife switches. There was a low correlation between the electric field strength and the magnetic field strength of the transmission and transformation system (0.410). There was no correlation between electric field intensity and noise. In the future, the electric field intensity pollution control for the above electrical equipment could be carried out for the high-voltage transmission and transformation system. In view
of the noise problem, switch stations and substations should be arranged as far away from the residents' lives as possible.

Acknowledgments
Financial assistance for this work from Analysis and Research on Electromagnetic Environment Impact of 750 kV Substation (2012101020).

References
[1] National Bureau of Statistics of China. (2017) China Statistical Yearbook (1986, 1996, 2006, 2017). China Statistics Press, Beijing.
[2] Zhai, J., Zhang, Y. (2004) Formation and prevention of electromagnetic radiation in 110 kV transmission line engineering. Northeastern Electric Power Technology, 26(3): 32–34.
[3] Wu, J., Li, Y., He, L., et al. (2017) Electromagnetic environment impact analysis in 110kV electric power transmission and transformation project in Huzhou District of Zhejiang Province from 2011 to 2015. Environment and Sustainable Development, 42(1): 149–150.
[4] Yimingjiang, P.: Informatization analysis on environmental impact of electromagnetic radiation of 220 kV transmission and transformation project in Xinjiang. Science and Informatization, 1(14): 71–72 (2018).
[5] Xie, A., Shi, Y., Zhou, X. (2009) Environmental impact on electromagnetic radiation of 220 kV power transmission and distribution project. Environmental Science & Technology, 32(2): 189–193.
[6] Li, W. (2015) Environmental impact analysis of electromagnetic radiation from power transmission and transformation projects: a case study of Zhangzhou, Fujian Province. Energy and Environment, 1(4): 16–17, 24.
[7] Yan, X., Tao, G. (2018) Analysis of electromagnetic environment impact of 500 kV transmission line in plain region. Uranium Mining and Metallurgy, 37(3): 216–221.
[8] Li, Y. (2008) Test and analysis of the electromagnetic environment at Eastern Yinchuan 750kV substation. Ningxia Electric Power, 1(6): 17–20.
[9] Wan, B., Zhang, G., Lu, Y., et al. (2007) Measurement on the electromagnetic environment of 750 kV Lanzhou-Guanting power transmission project. High Voltage Engineering, 33(5), 41–45.
[10] Zhu, H., Liu, J., Zhu, Z., et al. (2011) Measurement and analysis of audible noise in 500 kV transmission and transformation project. Electrotechnical Application, 30(13): 42–45.
[11] Ministry of Environmental Protection, General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. (2014) Controlling limits for electromagnetic environment (GB87202-014). China Environmental Science Press, Beijing.
[12] State Environmental Protection Administration. (1999) Technical regulations on environmental impact assessment of electromagnetic radiation produced by 500 kV ultrahigh voltage transmission and transfer power engineering (HJ/T 24-1998). China Environmental Science Press, Beijing.
[13] Ministry of Environmental Protection. (1999) Electromagnetic environmental monitoring method for AC electric power transmission and distribution project (on trial) (HJ681-2013). China Environmental Science Press, Beijing.
[14] National Health Commission of the People's Republic of China. (2018) Measurement of physical agents in workplace-Part 3: electric field and magnetic field between 1 Hz and 100 kHz (GBZ/T 189.3-2018). Beijing.
[15] Ministry of Environmental Protection, General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China. (2008) Emission standard of noise at boundary of industrial enterprises (GB 12348-2008). China Environmental Science Press, Beijing.