Supporting Capacity-Building Project Characteristics Test of Zhoushan Multi-Terminal HVDC Flexible Demonstration Project

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1. Introduction

The flexible direct current transmission technology is a new generation of DC transmission technology featuring fully controlled power electronics, voltage source converters and new modulation technologies. Compared with traditional DC transmission technologies, it has no need for reactive power compensation and no phase change. Failure problems, simultaneous adjustment of active power and reactive power, and low harmonic levels are suitable for the construction of multi-terminal DC systems and other obvious advantages [1]. They are widely used in grid-connected renewable energy, isolated islands, urban power supply, and wind power generation. Measure the weather and choose sunny weather [2-3].

This article selects Zhoushan multi-port flexible HVDC transmission demonstration project supporting test capacity construction project as the research object, and through the field measurement of the surrounding environment of the flexible DC cable test site, the environmental impact characteristics of the flexible DC cable test site are discussed.

2. Overview of Supporting Experimental Capacity Building Project of Zhoushan Multi-Station Flexible HVDC Transmission Demonstration Project

Zhoushan ±200kV five-terminal flexible DC transmission project is the first five-terminal flexible DC transmission project that has been successfully put into operation in the world. It is also the world's most flexible, direct-current DC project with the highest voltage rating, the largest number of terminals, and the largest single-ended capacity. The research object belongs to Zhoushan ±200kV five-terminal flexible DC transmission engineering technology reserve project. At present, the first DC 200kV flexible DC cable pre-assessment test has been carried out in the flexible DC test site of the Zhoushan multi-terminal flexible DC transmission demonstration project. The test aims to strengthen the islands under the jurisdiction of electrical contacts, enhance the structure of the grid, improve the reliability of power supply,
solve the flexible access of new energy such as offshore wind power, cable charging power and impact stability and power quality problems.

The main equipment in the test field of flexible DC cables is one set of 1200kV/50mA DC high voltage test equipment. It is mainly used for power cable type test, pre-qualification test, polarity reversal test and DC superimposed impulse voltage test, which can be 500kV and below. DC power transmission equipment withstand voltage test to provide power; Another thermal cycle system 1 set, can provide heating power for the cable system, mainly used for the heating of the cable sample conductor core. Among them, the 1200kV/50mA DC generator bears the heavy responsibility of providing test line voltage, it will be used for testing the corona characteristics and environmental impact of the line segment, as well as the on-line assessment of some equipment. It is one of the key test equipments for the base. The corona of the DC generator itself is closely related to the accuracy of future experimental results. The intensity of the corona depends directly on the surface field distribution of the generator components [4].

3. Engineering Environmental Impact Monitoring

3.1. Environmental Background Value

The monitoring results of the maximum synthetic field intensity in this project are 0.25-0.45kV/m, the 80% synthetic field monitoring results are 0.19-0.36kV/m, the DC magnetic field strength is between 48.1-49.4µT, and the radio interference frequency is 0.5MHz. The value is 39.4–52.4dB(µV/m) [5].

3.2. Measurement Items

This study selected power frequency electric field, power frequency magnetic field, synthetic field strength, DC magnetic field, radio interference, and noise as measurement items.

3.3. Measuring Instruments

Measurement instruments and corresponding technical parameters are shown in Table 1.

| Measuring instrument | Instrument model   | Measuring range                                      |
|----------------------|--------------------|------------------------------------------------------|
| Power frequency field analyzer | EFA300            | Power frequency electric field:0.7V/m–200kV/m; Power frequency magnetic field:4nT–87mT |
| Interference field strength meter | PMM9010/RA-01 | 0–134dB(µV/m)                                      |
| Synthetic field strength meter | HDEM-01           | -100kV/m~100kV/m                                    |
| Vector fluxgate magnetometer | FVM-400           | -100µT~100µT                                       |
| Sound level meter | AWA6270+           | 35dB(A)~130dB(A)                                    |

3.4. Measurement Points

| Measurement items | Flexible DC Cable Test Site |
|-------------------|-----------------------------|
| Power frequency electric field, power frequency magnetic field, synthetic field strength, DC magnetic field | 5m outside the wall of the flexible DC cable test site |
| Radio interference | 20m outside the wall of flexible DC cable test site |
| Noise | Placement of 1m outside the wall of the flexible DC cable test site |

3.5. Equipment Operation Conditions During Measurement

![Schematic diagram of measurement point distribution of flexible cable test field.](image)

Figure 1. Schematic diagram of measurement point distribution of flexible cable test field.
### Table 3. Operating conditions.

| equipment                  | Primary input voltage (V) | Primary input current (A) | High voltage output voltage (kV) | High voltage output current (mA) |
|----------------------------|---------------------------|---------------------------|---------------------------------|---------------------------------|
| DC voltage test device     | 251.1–259.0               | 3.9–4.1                   | -304.0–294.0                    | -1.40–1.20                     |

### Table 3. Continued.

| equipment                  | Circuit 1 current (A) | Circuit 2 current (A) | Circuit 3 current (A) | Circuit 4 current (A) |
|----------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
|                            | Test cable            | Analog cable          | Test cable            | Analog cable          |
| Thermal cycling equipment  | 751.6–814.4           | 747.7–810.2           | 576.1–650.7           | 580.8–653.9           |

#### 3.6 Measuring Weather Conditions

Choose good weather measurement in sunny days to avoid the influence of strong wind, rain, snow, hail and other weather [6].

#### 3.7 Measurement Results

### Table 4. Power frequency electric field intensity and magnetic field strength measurement results.

| Numbering | Point name                                      | Power frequency electric field strength(kV/m) | Power frequency magnetic field strength(µT) |
|-----------|-------------------------------------------------|---------------------------------------------|--------------------------------------------|
| 1         | 5m east-southeast                               | 0.018                                       | 0.174                                      |
| 2         | 5m to the southeast middle point                | 0.017                                       | 0.237                                      |
| 3         | 5m to the east of the northeast                 | 0.028                                       | 0.153                                      |
| 4         | 5m northeast of the northeast                   | 0.018                                       | 0.251                                      |
| 5         | 5m to the northwest                             | 0.018                                       | 0.236                                      |
| 6         | 5m to the southwest                             | 0.018                                       | 2.75                                       |
| 7         | 5m to the northwest side of the outdoor test site | 0.018                                      | 4.11                                       |
| 8         | 5m to the southwest side of outdoor test field  | 0.017                                       | 2.12                                       |
| 9         | Corresponding standard limit requirements        | 4                                           | 100                                        |

![Figure 2. Power Frequency Electric Field Measurements, Limits.](image1)

![Figure 3. Power frequency magnetic field measurement, limit value.](image2)
Table 5. Synthetic field strength monitoring results.

| Numbering | Point name                                      | Synthetic field strength(kV/m) | 80% | Maximum |
|-----------|-------------------------------------------------|--------------------------------|------|---------|
| 1         | 5m east-southeast                               | -0.30                          | -0.30|         |
| 2         | 5m to the southeast middle point                | 0.10                           | 0.15 |         |
| 3         | 5m to the east of the northeast                 | -0.10                          | -0.15|         |
| 4         | 5m northeast of the northeast                   | -0.10                          | -0.15|         |
| 5         | 5m to the northwest                             | -0.15                          | -0.20|         |
| 6         | 5m to the southwest                             | 0.05                           | 0.10 |         |
| 7         | 5m to the northwest side of the outdoor test site | 0.10                          | 0.10 |         |
| 8         | 5m to the southwest side of outdoor test field  | 0.05                           | 0.10 |         |
| 9         | Corresponding standard limit                    | 15                             | 25   |         |

Figure 4. Synthetic field strength 80% measurement value, limit value.

Figure 5. Synthetic field strength maximum measurement value and limit value.

Table 6. DC magnetic field strength monitoring results.

| Numbering | Point name                                      | DC magnetic field strength(µT) |
|-----------|-------------------------------------------------|-------------------------------|
| 1         | 5m east-southeast                               | 43.5                          |
| 2         | 5m to the southeast middle point                | 43.5                          |
| 3         | 5m to the east of the northeast                 | 44.5                          |
| 4         | 5m northeast of the northeast                   | 44.6                          |
| 5         | 5m to the northwest                             | 50.2                          |
| 6         | 5m to the southwest                             | 48.6                          |
| 7         | 5m to the northwest side of the outdoor test site | 50.5                          |
| 8         | 5m to the southwest side of outdoor test field  | 48.2                          |
| 9         | Corresponding standard limit                    | 10000                         |

Table 7. Radio Interference Monitoring Results.

| Numbering | Point name                                      | frequencyMHz | Radio interference field strength dB(µV/m) |
|-----------|-------------------------------------------------|--------------|------------------------------------------|
| 1         | 20m away from the southeast wall                 | 0.5          | 43.8                                     |
| 2         | 20m away from the northeastern wall              | 0.5          | 42.9                                     |
| 3         | 20m to the northwest                            | 0.5          | 40.8                                     |
| 4         | Outdoor test site 20m away                      | 0.5          | 48.8                                     |
| 5         | Corresponding standard limit requirements       | 0.5          | 53                                       |
Figure 6. DC magnetic field measurements, limits.

Figure 7. Radio interference measurements, limits.

Table 8. Noise Monitoring Results.

| Numbering | Point name                              | Noise dB(A) | Daytime noise | Night noise |
|-----------|-----------------------------------------|-------------|---------------|-------------|
| 1         | 1m east-southeast                       | 44.8        | 40.2          |             |
| 2         | 1m southeast of the middle point         | 45.2        | 40.9          |             |
| 3         | 1m to the east of the northeast         | 52.5        | 43.9          |             |
| 4         | 1m northeast of northeast               | 54.6        | 44.0          |             |
| 5         | 1m to the northwest                     | 61.5        | 49.8          |             |
| 6         | 1m to the southwest                     | 57.4        | 49.2          |             |
| 7         | 1m to the northwest side of the outdoor test site | 55.4     | 48.2          |             |
| 8         | 1m on the southwest side of the outdoor test site | 56.7     | 49.0          |             |
| 9         | Corresponding standard limit requirements | 65          | 55            |             |

Figure 8. Daytime noise measurements, limits.
3.8. Summary Analysis of Monitoring Results

From Table 4 to Table 8, Figure 2 to Figure 9, it can be seen that the strength of the composite field around the test field of the flexible DC cable is basically the same as the background value of the environment.

The power frequency electric field, power frequency magnetic field, DC magnetic field strength, radio interference intensity and noise around the test field of the flexible DC cable are all less than the corresponding standard limit requirements [7-10].

4. Conclusion

As the first pre-qualification test of flexible DC cables in China, the results obtained from the actual measurement of the surrounding environment of the flexible DC test site in the supporting experimental construction project of the Zhoushan multi-terminal flexible HVDC transmission demonstration project show that:

The flexible DC test field has less influence on the surrounding electromagnetic radiation environment. The influence of the synthetic field intensity generated by the project on the surrounding environment is negligible; the power frequency electric field, power frequency magnetic field, DC magnetic field, radio interference intensity, and noise generated by the project are much smaller than the corresponding standard limit values.

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