

一、特高压试验基地概述

特高压直流试验基地位于北京市昌平区，是中国国家电网公司为特高压工程建设需要而建立的 4 个试验研究基地之一。其余三个分别是特高压交流试验基地（湖北武汉）、特高压杆塔试验基地（河北霸州）、西藏高海拔试验基地（西藏羊八井 4300）。这四个试验研究基地构成了一套功能完整的特高压试验研究体系，主要进行一些工程需要的前期科学研究、基础性机理性研究以及设备型式试验等。

UHV DC Test Base is located in Changping district, Beijing. It is one of the four test bases constructed by SGCC for the UHV projects. The other three ones are UHV AC Test Base in Wuhan, Hubei Province, UHV Transmission Tower Test Base in Bazhou, Hebei Province, and High Altitude Test Base in Yangbajing, Tibet. Four test bases have constituted a fully functional UHV test and research system, which mainly focus on pilot scientific research, basic mechanism studies, and equipment type test for UHV projects.

四基地共创 30 余项世界第一，59 项专利，目前已开展 200 余项关键技术研究，为中国国家电网公司第一条特高压交流试验示范工程和第一条特高压直流示范工程的顺利建设和安全运行提供了重要的科学依据。

Four test bases have created more than 30 world records and obtained 59 patents. Up to now, over 200 key technical researches have been carried out, which provide the scientific basis for successful construction and operation of the first UHV AC and DC demonstration projects.

1. 特高压直流试验基地

特高压直流试验基地占地 26 万平米，由户外试验场、特高压直流试验线段、电晕笼、试验大厅、绝缘子及避雷器试验室、污秽及环境试验室、特高压直流换流阀试验室等 8 大部分组成。其中线段部分占地 18 万平米。于 2007 年 2 月 23 日全面开工建设，2009 年 2 月 22 日，通过总体验收。已被国资委授予特高压工程技术国家工程试验室。

UHV DC Test Base, covering 260,000m², mainly comprises eight parts: Outdoor test site, UHV DC test line section, Corona cage, Test hall, Arrester and insulator laboratory, Pollution and environmental laboratory, and UHV DC Thyristor valve laboratory, while the test line section covering 18,000 m². The Test Base started construction on February 23, 2007 and finished on February 22, 2009, which has been awarded the State Key Laboratory of UHV technology by the SASAC (State-owned Assets Supervision and Administration Commission of the State Council).

试验基地可以开展电磁环境、外绝缘、系统运行安全、设备试验技术与运行特性等方面的全方位试验研究。

Comprehensive researches can be carried out in the test base, such as simulate electromagnetic environment, external insulating, safe operation of power system, equipment test technology, and operating characteristics.

截至目前，试验基地开展了±1000kV、±800kV、±660kV 等多个电压等级 40 余项关键技术研究项目，已成功应用于宁东—山东±660kV、向家坝—上海±800kV、镜屏—苏南±800kV 直流输电工程中，开展的±1000kV 级直流输电系统系列科研项目为今后±1000kV 输电工程设计提供了参考依据。

试验基地还承担了意大利、日本、印度等国家特高压产品的委托试验。

Up to now, more than 40 key technical researches have been carried out on $\pm 1,000\text{kV}$, $\pm 800\text{kV}$ and $\pm 660\text{kV}$ voltage levels, which have been successfully used in $\pm 660\text{kV}$ Ningdong-Shandong, $\pm 800\text{kV}$ Xiangjiaba-Shanghai and $\pm 800\text{kV}$ Jingping-Sunan DC transmission projects. Furthermore, studies on $\pm 1,000\text{kV}$ DC system provided reference for the design of $\pm 1,000\text{kV}$ transmission projects.

The test base has also undertaken the consigned tests of UHV products for Italy, Japan, India and other countries.

二、特高压直流试验基地试验设施

1、污秽及环境试验室

采用直径 20 米、高 25 米的金属罐体式结构，是我国目前最大的高原综合复杂气候环境模拟试验室，具有污秽-覆冰-淋雨-低气压多功能，同时，它可为不同行业的高原环境试验提供场所。可应用于小型直升机、高原军需装备、车辆及其他高原装备的整机环境考核。

（功能）进行直流 $\pm 1000\text{kV}$ 电压等级、交流 1000kV 电压等级长串绝缘子、站用支柱绝缘子及大型套管等在不同海拔条件下(最高模拟海拔 5500 米)的污秽、覆冰和淋雨等外绝缘特性试验。

（设备）

人工气候罐及其保障系统

800kV/6A 试验变压器

$\pm 1000\text{kV}/2\text{A}$ 直流电压发生器

(成果)

- 自 2009 年初至今，本试验室已经圆满完成和正在开展多项有关绝缘子串和站用支柱绝缘子在不同气候环境下的污秽外绝缘与覆冰外绝缘的科技项目。

Pollution and environment laboratory

With the diameter of 20m and height of 25m, the metallic canned chamber is the largest multi-functional pollution and climate laboratory in China. It can realize various artificial climate and environment conditions, including pollution, ice coating, rain spray, and low air pressure. At the same time, it can work as high altitude test site for many industries, such as small helicopter, altitude military equipment, vehicles and other altitude equipment to do the environment assessment.

Pollution and environment lab can perform DC $\pm 1,000\text{kV}$ and AC $1,000\text{kV}$ pollution, ice covering, and rain spray tests for long string insulators, station-use post insulators, as well as large sized bushings under different altitude conditions (with the highest simulation altitude of 5500m).

It comprises artificial climate tank and its support system, $800\text{kV}/6\text{A}$ testing transformer, and $\pm 1000\text{kV}/2\text{A}$ DC voltage generator.

Since the beginning of 2009, the laboratory has successfully accomplished and been carrying out a number of pollution and ice covering external insulation researches for long rod insulators, station-use post

insulators under different climate environment.

2、户外试验场

主要用于进行 $\pm 800\text{kV}$ 电压等级特高压直流输电工程的外绝缘特性试验研究，包括输电线路和换流站、变电站设备和空气间隙的外绝缘等，同时兼顾 $\pm 1000\text{kV}$ 直流输电系统研究的要求。

户外试验场选用了 $7.2\text{MV}/480\text{kJ}$ 冲击电压发生器和 $\pm 1600\text{kV}/0.5\text{A}$ 直流电压发生器设备，设计建造了净空尺寸 $50\text{m}\times 60\text{m}$ 的门型塔和两座 45m 高的锚塔。

除了完成科研工作外，户外试验场还完成了多项重要的外委试验工作，其中包括国际上的委托试验，如由日本 NGK 公司委托对为印度电力公司生产的大吨位瓷绝缘子进行的型式试验。这项试验工作量大，试品布置有较大难度。试验的完成受到了国外公司的高度评价，提高了试验基地在国际上的知名度。

Outdoor test site

Outdoor test site mainly focuses on the research of external insulation characteristics of $\pm 800\text{kV}$ UHV DC transmission projects, including transmission line, equipments in convertor station and substation, and air gap, while taking account of the research requirements of $\pm 1000\text{kV}$ DC transmission system.

The facilities mainly include: $7200\text{kV}/480\text{kJ}$ outdoor impulse voltage set equipments, $1600\text{kV}/0.5\text{A}$ DC voltage generator, one $50\text{m}\times 60\text{m}$ gate tower, and two tension anchor towers.

Besides the scientific researches, a number of important external consigned tests have been carried out in the outdoor test site, including international ones, such as the type test of large-tonnage porcelain insulator produced by Indian Power Corporation, which is commissioned by NGK Company. This test has heavy workload and the test items arrangement is quite difficult. The successful accomplishment was highly appraised by foreign companies, which greatly improved the international awareness for the test base.

3、试验大厅

试验大厅是研究交、直流输电技术和运行技术必备的试验研究设施之一。

试验大厅的净空尺寸为 86m×60m×53m（长×宽×高）。

特高压直流试验基地的试验大厅为特高压等级，其主要功能是研究特高压交、直流输变电设备的内、外绝缘性能，如变压器、电抗器、GIS 组件、避雷器、绝缘子和套管等。

- (1) 输变电设备（包括部件）工频、直流耐受及放电试验。
- (2) 输变电设备（包括部件）雷电冲击、操作冲击耐受及放电试验。
- (3) 设备介损、局部放电试验。
- (4) 导线（跳线）、金具和绝缘子可见电晕及无线电干扰试验。
- (5) 设备绝缘子、套管人工淋雨试验。
- (5) 塔头间隙放电试验。
- (6) 雷电机理及防雷新技术试验。
- (7) 输变电设备性能检测方法的研究。
- (9) 变压器、电抗器、绝缘子、避雷器等产品的型式试验、进出口产品检验、产品质量仲裁检验。

冲击电压发生器、工频试验变压器及直流电压发生器，这三大主设备的成套装置。

为实现局部放电和无线电干扰试验时不受外界电磁波干扰的功能，并能开展电晕特性等相关的试验研究，大厅需采取六面屏蔽措施。

Test Hall

Test hall is one of the necessary facilities for DC/AC transmission and operation technology.

The dimension of test hall is $86\text{m} \times 60\text{m} \times 50\text{m}$ (high). Its electromagnetic shielding ability reaches 70dB.

The main function of test hall is to perform researches on both internal and external insulating capabilities of UHV DC power transmission and transformation equipments, including transformer, reactors, GIS, arrestors, insulators, and bushings. The tests mainly include:

- 1) Power frequency test, DC voltage withstanding test and discharge test of transmission and transformation equipments (including components)
- 2) Lightning and switching impulse test
- 3) Dielectric loss test and partial discharge test
- 4) Visible corona and radio interference tests of wires (jumper), metal fittings and insulators
- 5) Artificial rain spray test of insulators and bushings
- 6) Air gap discharge test of transmission tower
- 7) Lightning mechanism test and new technology test for lightning protection

8) Researches on property inspection methods of transformer and transmission equipments

9) Type test of transformer, reactor, insulator and arrester, quality inspection of import and export products, and quality arbitration tests

Main equipments include: 1500kV power frequency testing transformer, ± 2400 kV DC voltage generator, and 6MV impulse voltage generator.

In order to avoid the interference from external electromagnetic wave during the partial discharge test and radio interference test, and study the corona characteristic, the test hall has been electromagnetic shielded at six surfaces.

4、避雷器试验室

避雷器试验室应具有进行直流超特高压避雷器各项电气性能测试的手段和开展特高压避雷器电气性能试验研究、测试、检验及试验方法研究的能力，可进行 $\pm 800 \sim \pm 1000\text{kV}$ 避雷器元件的主要型式试验，这主要包括：

- 雷电、操作和陡波冲击电流试验
- 直流老化性能试验
- 动作负载试验
- 分流特性试验

避雷器试验室需要根据特高压直流避雷器的特点，开发研制新的试验装置，建立必要的试验手段，配备的主要试验设备应包括：冲击电流发生器（陡波、雷电、操作、缓波前、大电流、长持续时间等各种波形）、动作负载试验设备、加速老化试验设备、分流特性试验设备、直流背靠背电源等。

Arrester laboratory

The arrester laboratory has devices to test various electrical performances of UHV DC arresters, and the capability to do electrical properties research, test, inspection and the study of test method for UHV arresters. Main type tests of $\pm 800 \sim \pm 1000\text{kV}$ arresters can be carried out here, including:

- Lightning, switching and steep current impulse test
- DC aging test
- Operating duty test
- Shunting characteristic test

According to the characteristics of UHVDC arresters, the laboratory has developed new experimental devices and set up necessary test methods, while the main equipments including: impulse current generator (Steep waves, lightning, switching, slow front, high current, long duration, and other waveforms), operating duty test device, accelerating aging test device, shunting characteristic test equipment, BTB DC voltage generator, etc.

5、 Insulator lab.

The dimension of insulator lab is 29m×32m×25m (high). The lab has the world-class crackle and thermal mechanical machine, focusing on electrical/mechanical and material property tests of insulators and bushings in UHV DC transmission projects, such as tension and load test, crackle test, thermal mechanical and electromechanical test, and power frequency, DC, lightning and steep front impulse voltage tests

The facilities mainly include:

1200kV impulse voltage generator

500kV power frequency test transformer

600kN thermal mechanical test machine

2000kN/15m tension machine

700kN m/14m crackle test machine.

Insulator lab has successfully performed the world's first UHV large tonnage post insulator bending failure load test in May, 2008.

6、 UHV DC test line

The total length of UHV DC test line is 1080m, which is the longest double-circuit test line in the world. The test line has been put into operation on June 28th 2007, which comprises 3 spans, while the middle span is for measurement and the length is 300m.

The test line section comprises a DC voltage source and 6 towers. The DC voltage source is a $\pm 1200\text{kV}/0.5\text{A}$ dipole DC generator. 6 towers are a terminal tower, a polarity transposition tower, two gate towers and two tension towers, while the gate tower's height is 88m and its width is 80m. Two adjustable beams are installed on each tower, so the test line can be moved continuously in horizontal and vertical direction.

The main functions of test line section are to examine electromagnetic environment of EHV/UHV DC transmission line, to find out, associated with corona cage tests, UHV DC transmission line electromagnetic environment prediction methods, and combined with electromagnetic environment simulation tests, to perform researches on the electromagnetic environment of different EHV/UHV DC transmission line layouts.

7、Corona cage

It is the world largest corona cage with dimension of 70m×22m×13m (high) and double frames, while the frame can be removed. In this cage, we can research DC corona characteristics of UHV conductor, such as radio interference, audible noise and corona loss. The cage could simulate the natural conditions such as fog and rain.

In order to meet requirements of the UHV DC project and promote domestic production of $\pm 800\text{kV}$ UHV DC equipments, lots of researches have been accomplished, such as the external insulation test, and corona test. The result strongly supported to Xiangjiaba-Shanghai UHV DC demonstration project.

设计和建设±800kV 直流输电工程，可以部分借鉴国外的研究成果，但因我国气象条件复杂，而不同的大气环境对高压试验研究结果包括电磁环境的影响都很大，各国研究得出的结果也有差异，因此，必须根据我国国情进行大量的试验研究工作，并总结超高压直流工程的经验来合理解决电磁环境问题。为此，国家电网公司决定在特高压直流试验基地建设特高压直流试验线段，用于研究特高压直流线路的电磁环境，包括合成电场、离子流密度、无线电干扰和可听噪声等。

The design and construction of $\pm 800\text{kV}$ HVDC projects can partly use results of foreign researches, but because of the different atmospheric environment which has big impacts on HV tests results, like electromagnetic environment, the results of different countries vary. For the complex weather conditions in China, it is necessary to conduct many tests based on China's national conditions, and summarize the experience of EHV DC projects to solve electromagnetic environment problems. To this end, SGCC has decided to construct the UHV DC test line section in UHV DC base to study the electromagnetic environment of UHV DC lines, including combined electric field, ion current density, radio interference and audible noise.