High Voltage Engineering

Introduction

1. The development of HV power transmission
2. The current situation and prospects of China's electric power industry
3. Special issues under high voltage & high electric stress
4. Special phenomena under HV and their applications

Xidong LIANG

2025-2-20

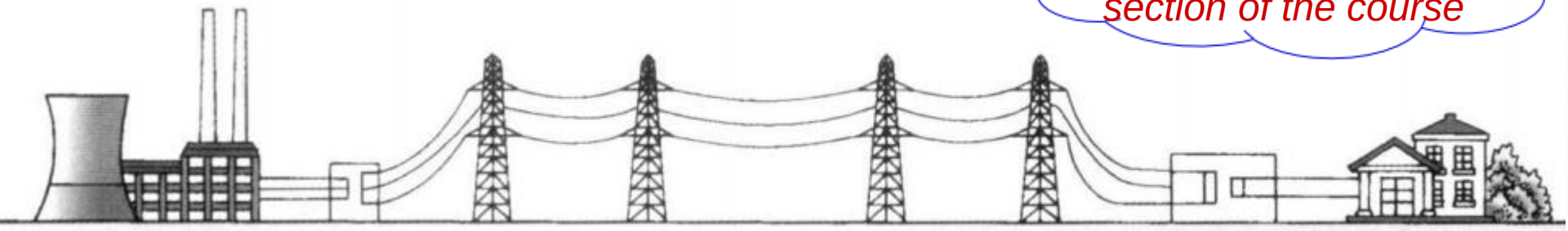
1. The development of HV power transmission

- Why does modern society need power transmission? Why is the HV transmission necessary?
- How did HV power transmission develop in the past?
- What is the relation between HV power transmission and HV power grid?

Engineering technology has its real demand

- What is the role of electricity in modern society?
- What is the most basic physical law of the power grid?
- What is the material foundation of a HV power grid?
- What are the requirements of the new power system for power transmission and the large power grid?

Summarize questions and perspectives for each section of the course



power plant substation HV lines substation end user

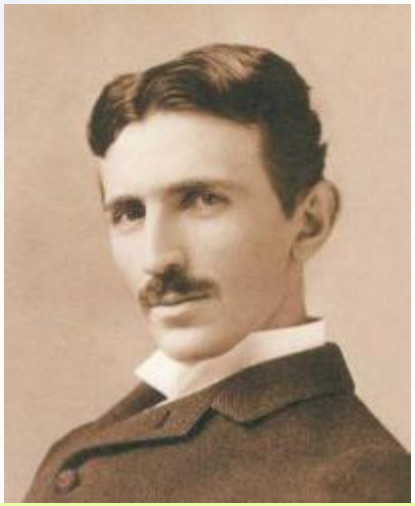
1. The development of HV power transmission

1.1 The emergence of HV power transmission and the increasing of voltage levels

Thomas Edison
(1847-1931)

The large-scale transmission of electrical energy is the foundation for the widespread application of electrification.

HV power transmission is the most important technology to achieve large-scale transmission of electrical energy.



Nikola Tesla
(1856-1943)

1. The development of HV power transmission

1.1 The emergence of HV power transmission and the increasing of voltage levels

In 1893, the Chicago World Expo (Columbus Exposition) in the United States fully adopted electric lighting for the first time, marking the arrival of the era of electrical lighting.

In 1894, the Niagara Falls hydroelectric power station was transported to Buffalo using a three-phase AC system, ending the debate between DC and AC transmission represented by Edison and Tesla since 1880.

"For most scientists the invention of rotating magnetic field was one of the greatest successes of human imagination in the world history"—150 anniversary of Tesla

Large scale power transmission begins with **AC high-voltage power transmission**

Will it be higher?

The increasing of voltage level and the formation of a large power grid

The time when each voltage level of AC power transmission first appeared

Voltage/kV	10	50	110	220	287	380	525	735	1150
Year	1890	1907	1912	1926	1936	1952	1959	1965	1985

The voltage level of power transmission in the world has increased **100 times in 100 years**!

Electrification is one of the most prominent symbols of industrial civilization

- The large-scale transmission of electrical energy is the foundation for the widespread application of electrification
- HV power transmission is the most important technology to achieve large-scale transmission of electrical energy

Why HV is used in power transmission?
Are there any advantage when increasing voltage level?

The character of "electricity": in engineering sense, it cannot be stored on a large scale

(commercial products: production, transportation, consumption)

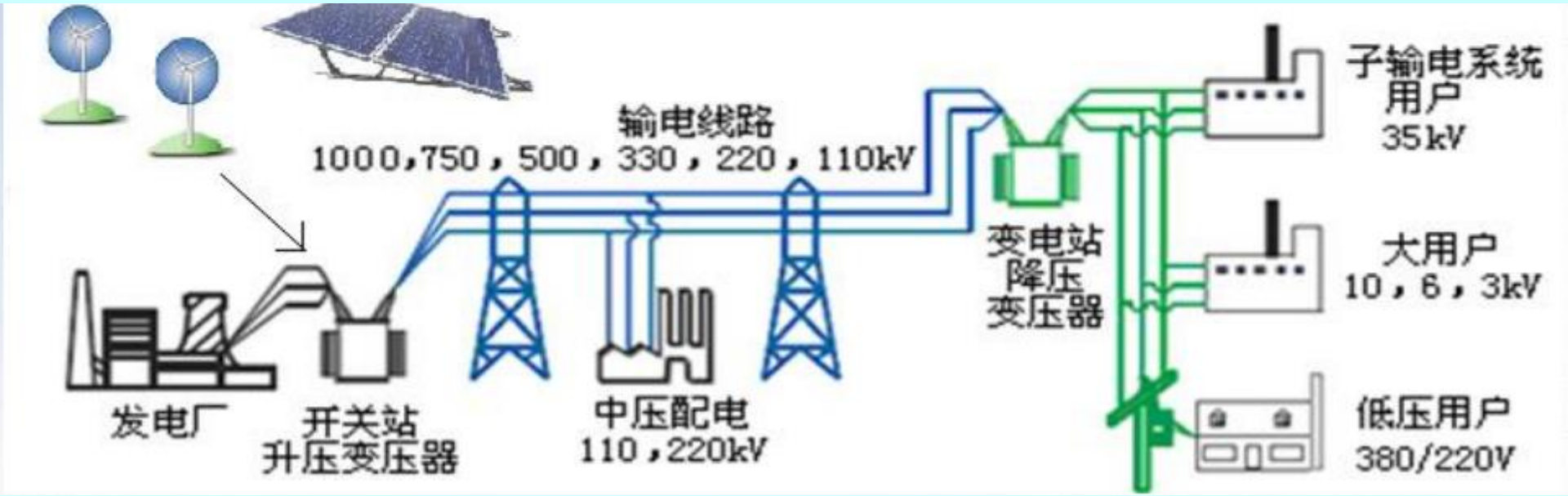
- The electricity generated in every moment within the entire power grid must be consumed at the same moment !

Many characteristics of the power system are determined by this character!

Using adjustable power generation to match the changing electricity demands

Significant advantages of a large power grid: connecting many power generators and numerous consumers

Why must the power grid be high-voltage?



Facing the same big power grid, different concerns from different people


Central European
Power Grid 2017.12
THE NETHERLANDS
BELGIUM
GERMANY
POLAND
LANTIC OCEAN
CZECH REPUBLIC
SLOVAKIA
AUSTRIA
FRANCE
HUNGARY
SLOVENIA
CROATIA
BOSNIA
HERZEGOVINA
MONACO
SAN MARINO
ITALY
ADRIATIC SEA
MONTENEGRO

The character of "electricity": in engineering sense, it cannot be stored on a large scale. The electricity generated in every moment within the entire power grid must be consumed at the same moment !

- **Why must the power grid be high-voltage?**
  Why do we need **long-distance** and/or **bulk power transmission**?

- Significant advantages of a large power grid: connecting many power generators and numerous consumers
- Large capacity centralized power generation has high efficiency and convenient pollution control, and large power plants are not located in concentrated electricity consumption areas
- High voltage ensure the long distance power transmission and with low losses, and is convenient to create large-scale power networks(**thanks to HV power transmission!**)
- The past development of large power grids: from separate point to an area, from local to regional, and from low voltage to high voltage

- **High voltage power grid:** huge energy can be instantly and efficiently delivered over long distances with low loses and balanced covering a large area! plug and play

- **What changes will occur in the future power system? What needs to be done?**

The character of "electricity": in engineering sense, it cannot be stored on a large scale. The electricity generated in every moment within the entire power grid must be consumed at the same moment !

- **Why must the power grid be high-voltage?**
  Why do we need **long-distance and/or bulk power transmission**?

- **High voltage power grid:** huge energy can be instantly and efficiently delivered over long distances with low loses and balanced covering a large area！ plug and play

- **What changes will occur in the future power system? What needs to be done?**

- **Demand:** Huge fluctuations in energy and uncertain power consumption across a wide range, achieving instant balance across different regions
  - Intelligent scheduling control and operation protection for instantaneous balance of large-scale and huge fluctuations in energy
  - Intelligent prediction and effective guidance of electricity demand and generation conditions
  - Significant improvement and intelligent perception of power transmission capacity, energy storage capacity, and health status of power transmission/distribution equipments

1.2 AC ultra-high voltage power transmission

AC overhead lines $P = U^2 / Z$

system voltage, U kV	220	330	500	750	1000
surge impedance, Z Ω	400	303	280	260	250
surge impedance loading, P GW	0.12	0.36	0.9	2.2	4. 0
transmitted power, GW	0.1-0.2	0.2-0.5	0.4-1	1-2.5	2–5

Power transmission capacity of short lines is usually higher than SIL, while that of long-distance lines is lower than SIL

For transmission lines, HV(high voltage), 220kV and below
EHV(extra high voltage) , 330-750kV
UHV (ultra high voltage), 1000kV and above

If the voltage level is high, the technical difficulty is high, and UHV is really challenging the limits of transmission technology

1.2 AC ultra-high voltage power transmission

International research on UHV AC power transmission technology began in the late 1960s.

- **Soviet Union**: 1236km AC 1150kV (max. 1200kV) power transmission line constructed in 1985, and after 4 years of intermittent operation from 1989 to 1992, it was reduced to 500kV for operation
- **Japan**: Over 300 km of 1000kV (max. 1100kV) transmission lines, double circuit at one tower, constructed in the 1990s, but never operated at 1000kV (no UHV power station constructed)
- **USA, Italy, France, Brazil, and others**: research has been conducted but actual projects have not been built for the purpose of large capacity and long-distance power transmission, or save line corridors

After the 1990s, the economic growth rate of various countries generally but significantly declined, and the growth of electricity demand gradually slowed down, leading to the stop of research on UHV power transmission.

1.2 AC ultra-high voltage power transmission

International research on UHV power transmission technology began in the late 1960s.

After the 1990s, the economic growth rate of various countries generally but significantly declined, and the growth of electricity demand gradually slowed down, leading to the stop of research on UHV power transmission.

In recent years, renewable energy generation made rapid progress, and some countries constructed a large number of distributed renewable energy sources in areas where conditions permit.

After China's accession to the WTO in the new century, the manufacturing industry has shifted significantly to developing countries.

All above issues reduced the demand of large capacity or long-distance power transmission in developed countries.

However, the pressure on the power transmission corridor continues to increase, making it very difficult for new lines to be approved, and it is necessary to increasing the power transmission capacity per corridor.

1.2 AC ultra-high voltage power transmission

- In recent years, India also started constructing 1150kV AC and 800kV DC power transmission projects
- Currently, the highest voltage level of commercial power transmission lines in foreign countries is only 750kV. The longest operating experience for 750kV lines in countries such as USA, Canada, Russia, Brazil, South Africa, India, and South Korea is about fifty years

- China experienced three waves debate on UHV AC power transmission technology when constructing the large-scale 500kV power grid
- On Jan.6, 2009, the Jindongnan-Nanyang-Jingmen UHVAC testing and demonstration project (rated 1000kV, max. 1100kV) was successfully put into operation and has been operating safely to this day
- Only in China, UHVAC power transmission operates for a long time
- Exercises: how many UHV AC projects have been put into operation and under construction, and how long the operated UHV AC lines up to now?

Specific Topic: Development of voltage levels in China's power grid

1.3 Long distance high-capacity DC power transmission

Roughly number: AC over head lines (OHLs) can transmit power for 100km with 100kV

HVDC OHL is not limited by distance, therefore long-distance power transmission often adopts HVDC project

HVDC OHLs $P = U \times I$

rated voltage **kV**	**±500**	**±660**	**±800**	**±1100**
rated current **kA**	**3**	**3**	**3 - 5**	**4 - 5**
bi-pole capacity **GW**	**3**	**4**	**4.8 - 8**	**8.8 - 11**

HVAC OHLs $P = U^2 / Z$

System Voltage	**kV**	**220**	**330**	**500**	**750**	**1000**
natural power (SIL)	**GW**	**0.12**	**0.36**	**0.9**	**2.2**	**4.0**
transmitted power	**GW**	**0.1-0.2**	**0.2-0.5**	**0.4-1**	**1-2.5**	**2-5**

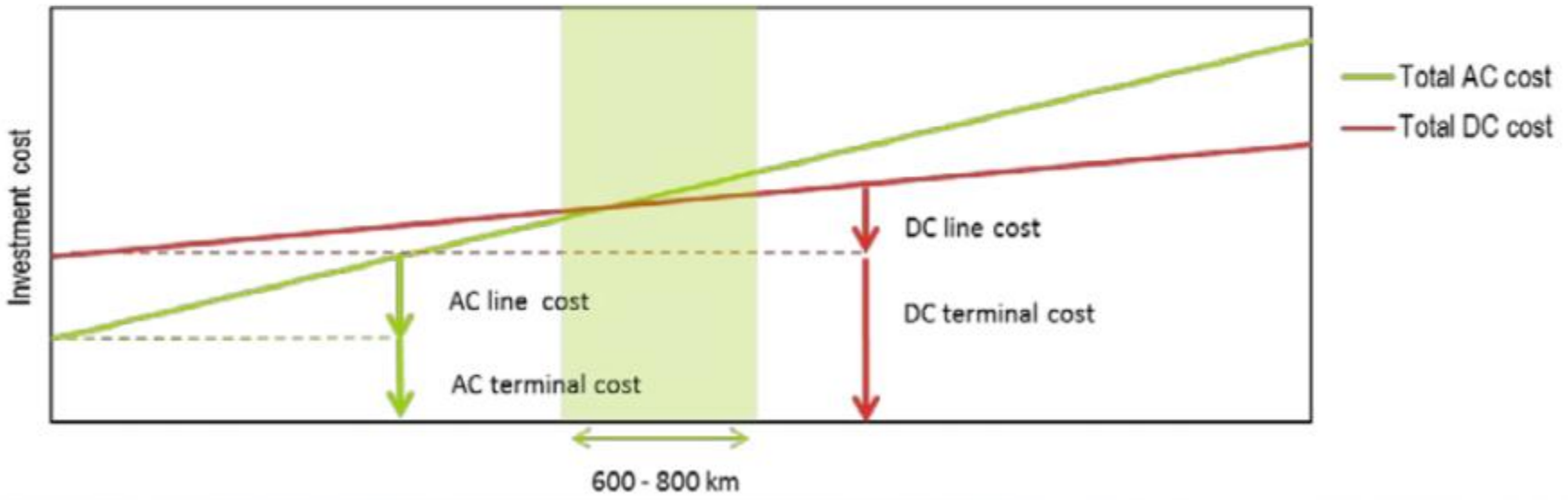
1.3 Long distance high-capacity DC power transmission

Roughly number: HVAC OHLs can transmit power for 100km with 100kV while HVDC OHL is not limited by distance

"Economic distance " : If the power transmission distance is shorter than the "economic distance", HVAC power transmission will present the economic advantage

Therefore, HVDC is often used for long-distance power transmission

Figure 3 • Relative economics of HVAC vs HVDC for interconnecting power systems



1.3 Long distance high-capacity DC power transmission

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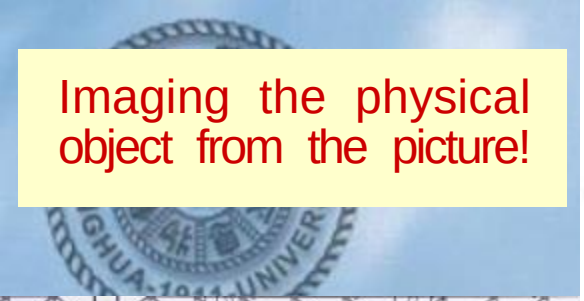
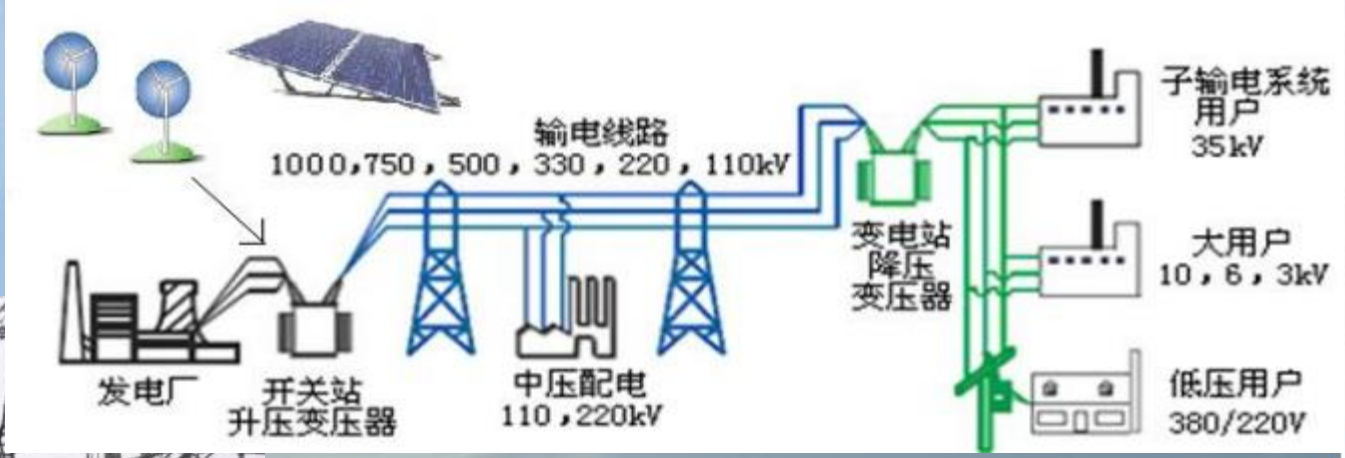
Therefore, HVDC is often used for long-distance power transmission

- Dozens of long-distance and high-capacity power transmission projects in China adopted HVDC
- From 2009 to 2010, China reached a new level of ± 800kV UHV DC
- Exercises: how many UHV DC projects have been put into operation and under construction, and how long the operated UHV DC lines up to now?
- ± 1100kV UHVDC project, 3340km from Zhundong to East China, started construction on June 1, 2016, energized on Dec. 31, 2018
- China is the only country in the world that has put UHVDC projects into commercial operation

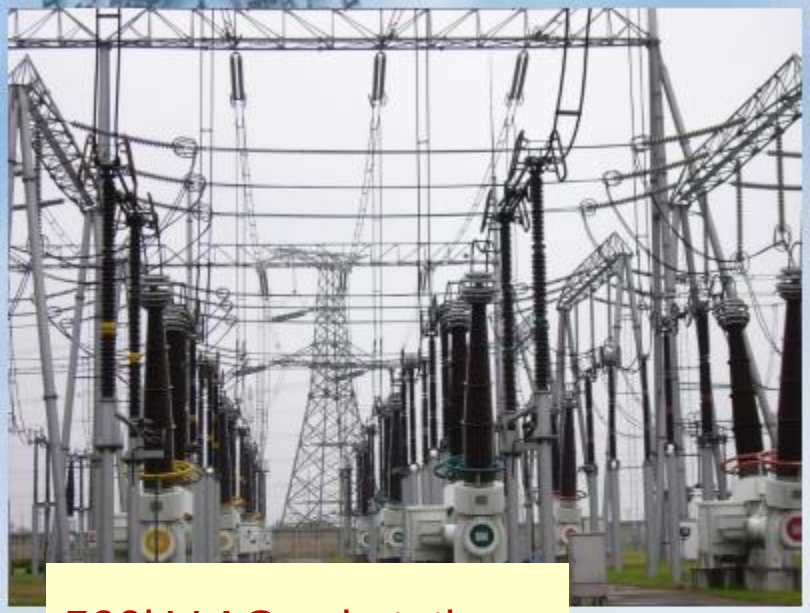
Imaging the physical object from the picture!





How is electricity transmitted? Substation + overhead lines

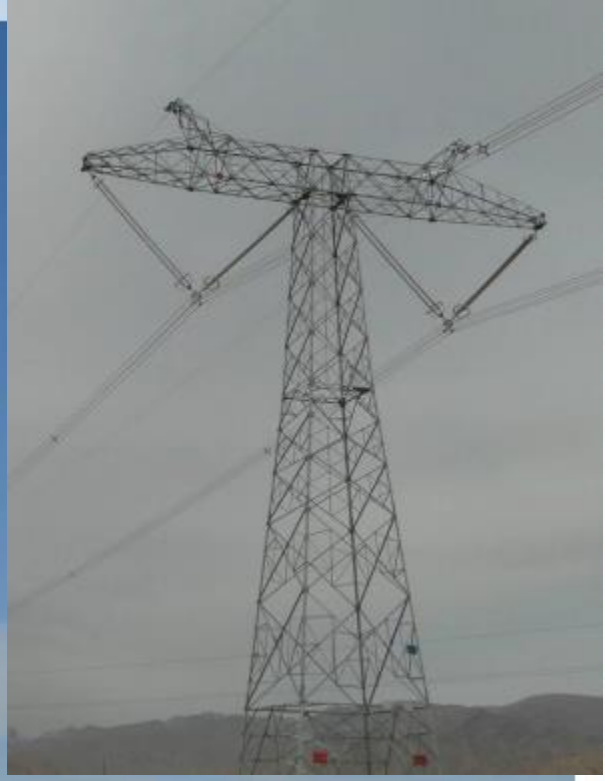
How to Bridge the Gap between Industry and Universities?



500kV AC substation

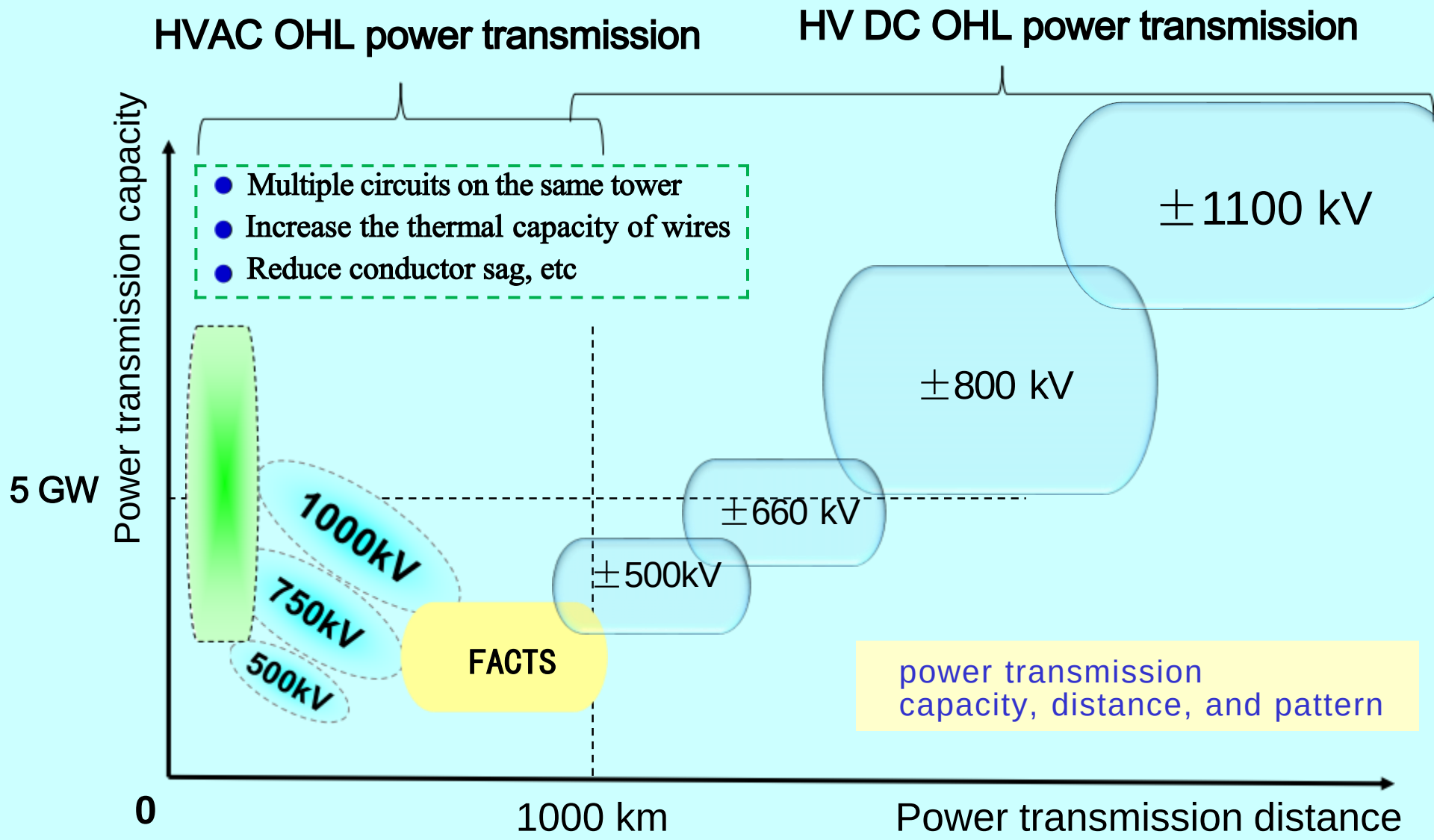
1000kV AC substation

750kV AC substation

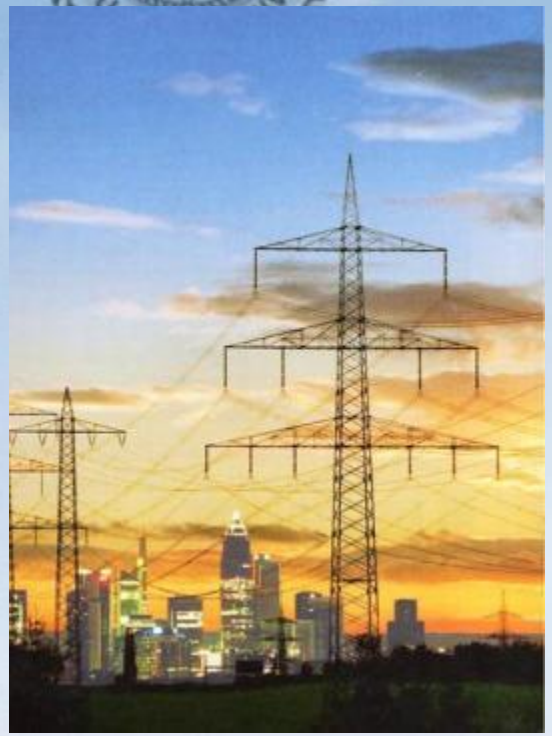


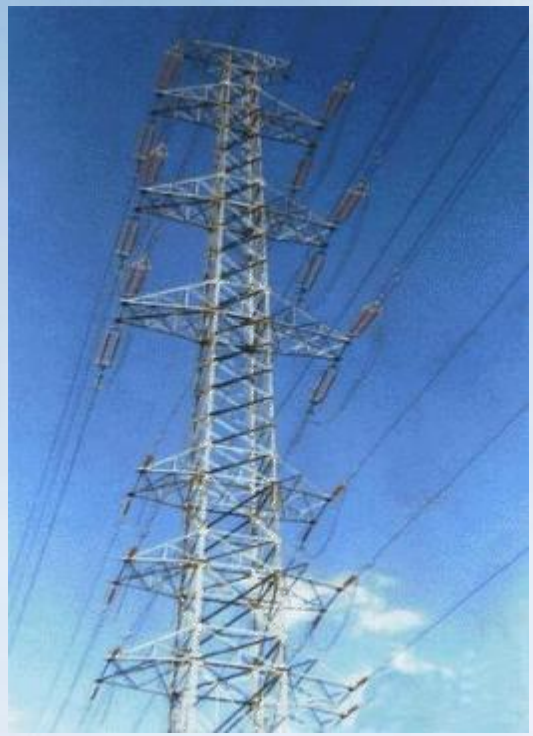
Specific Topic: Over Head Line

◆ HV power transmission is the most important technology to achieve large-scale transmission of electrical energy



1.4 Resource saving & environmental friendly power transmission pattern





OHLs with multiple circuits in one tower

Is HV power transmission environmental friendly?

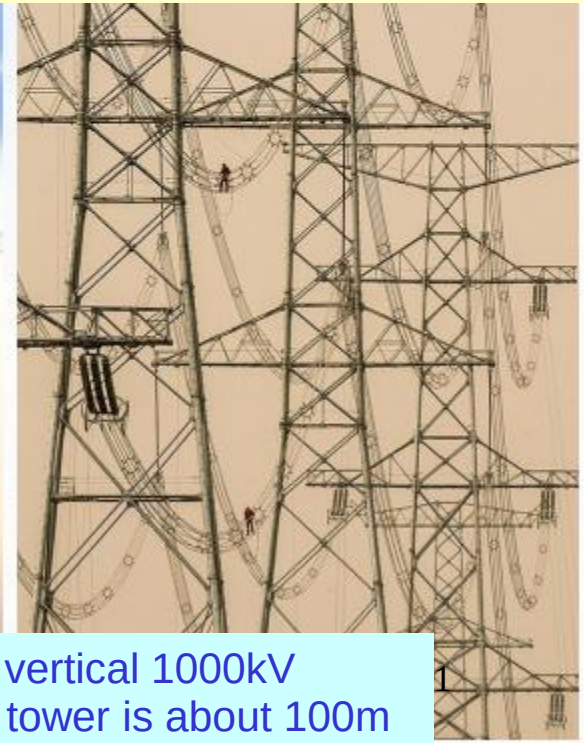
Specific Topic: Electromagnetic environment of OHLs

1.4 Resource saving & environmental friendly power transmission pattern

Multiple circuit in one tower:

- Many OHLs with 2×500kV+2×220kV circuits in one tower in the Yangtze River Delta, Pearl River Delta, Beijing-Tianjin regions
- Four circuits of 500kV in one tower have also been in operation for many years
- 2×1000kV+2×500kV four circuits in one tower were adopted in the UHVAC OHL from Huainan-Nanjing-Shanghai, which was put into operation on April 3, 2016, is within a 22km section out of the Suzhou Station

The Statue of Liberty, 93m high



The height of vertical 1000kV double circuit tower is about 100m

1.4 Resource saving & environmental friendly power transmission pattern

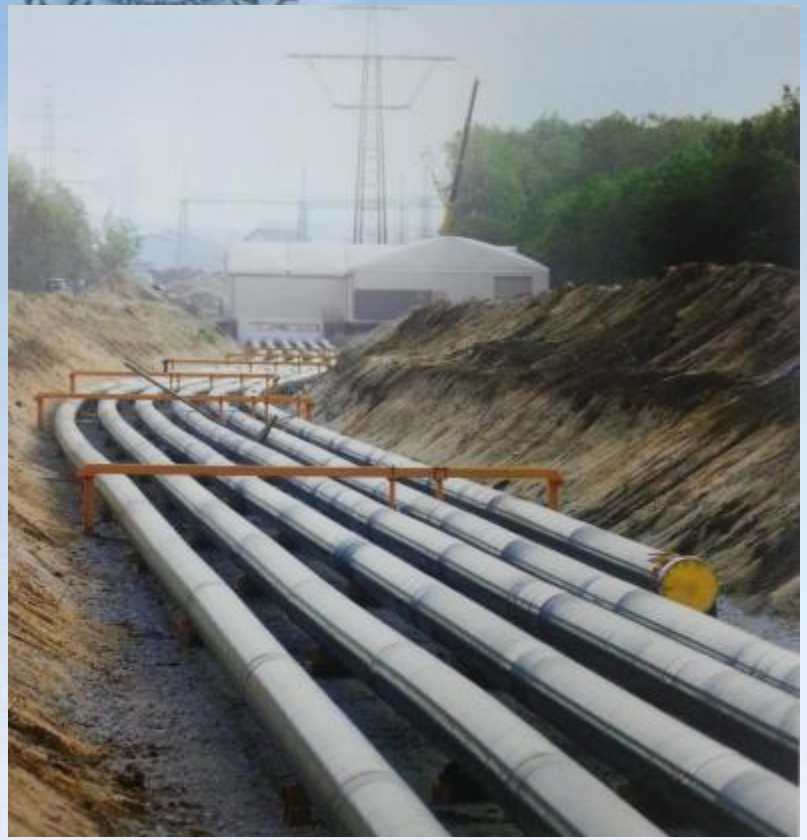
Compact OHL, China

Conventional tower with horizontal OHL

Compact OHL, Brazil

What are the advantages, disadvantages, and difficulties of compact OHLs, which normally with high SIL?

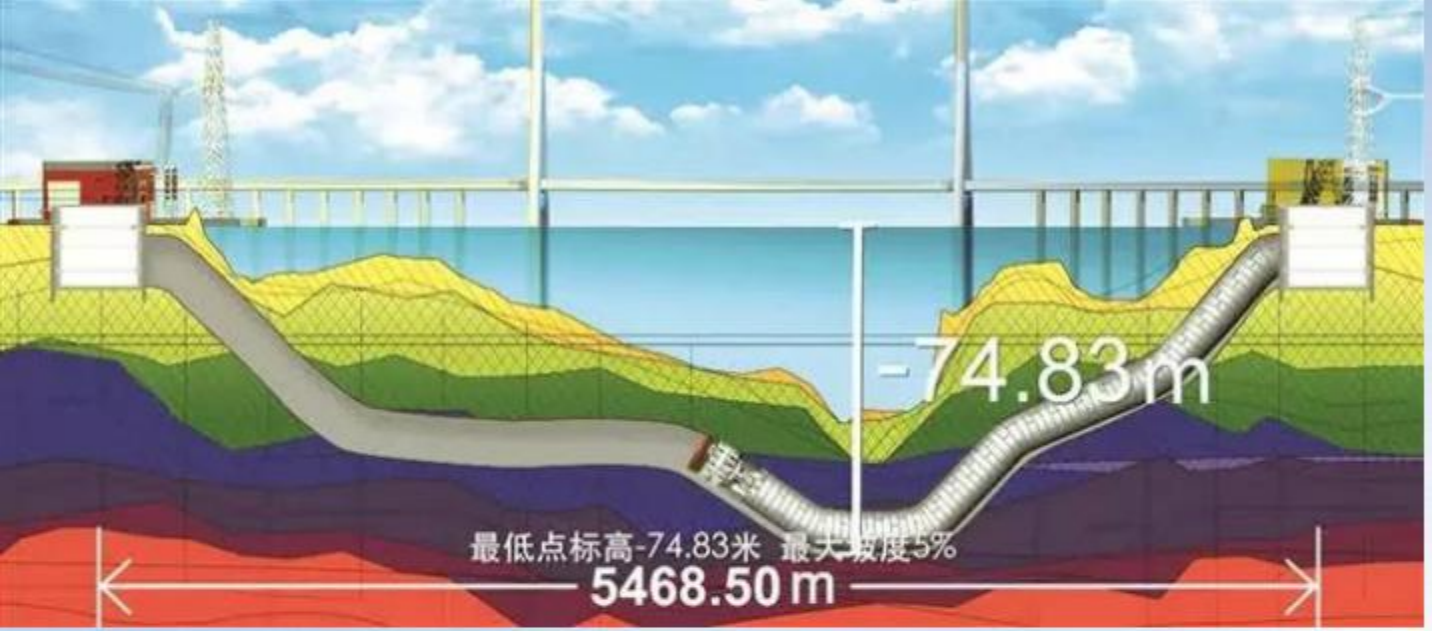
1.4 Resource saving & environmental friendly power transmission pattern

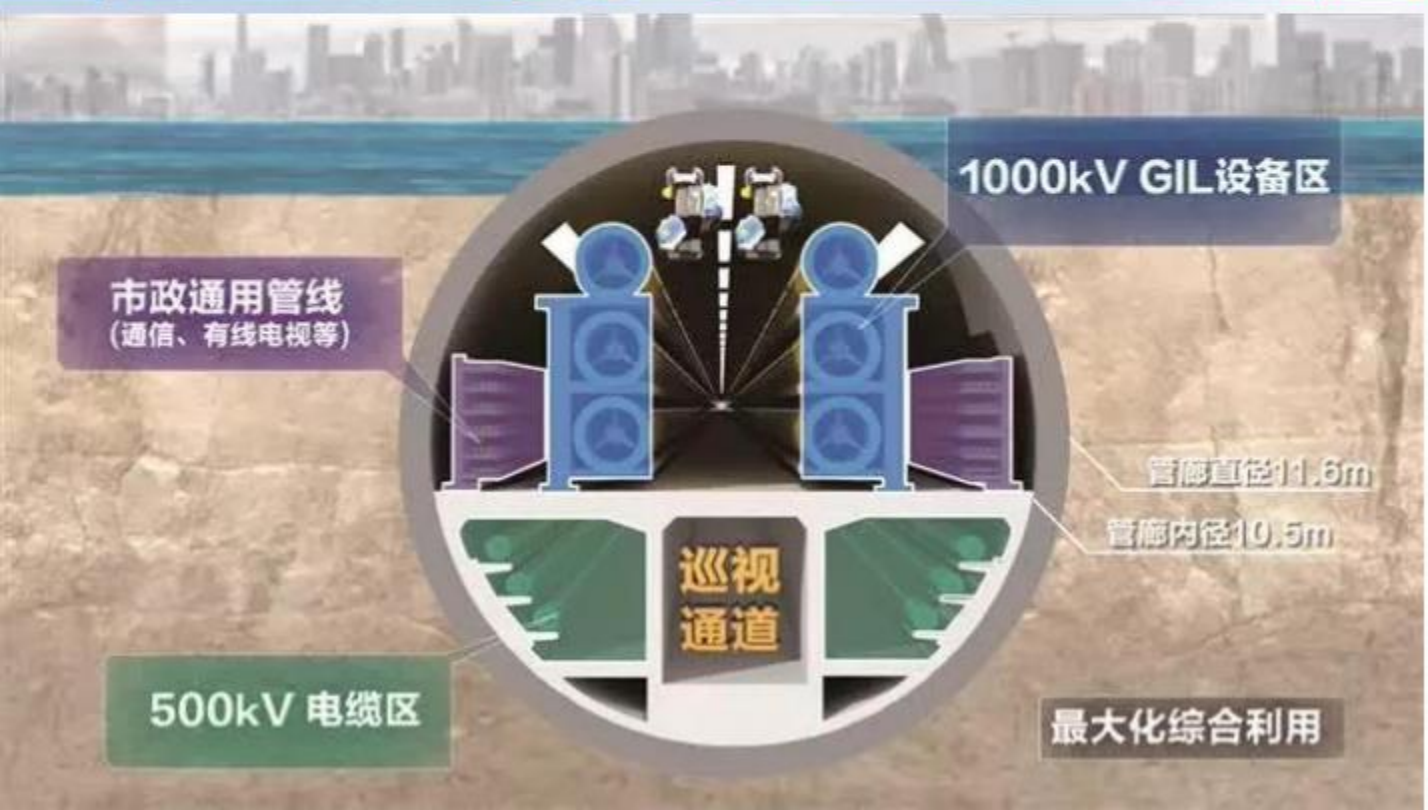


GIL: Gas insulated transmission line

What are the advantages, disadvantages, and difficulties?

Specific Topic: Overhead line and GIL





Su-Tong 1000kV GIL crossing the Yangzi River, put into operation on Sept 26, 2019

High Voltage Engineering

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2. Current situation and prospects of China's power industry

From the perspective of HV power transmission and large power grid

- **The power industry itself :**

  Basic national conditions, scale, distribution, growth rate, trend, and technology development……

- **Outside views on the power industry :**

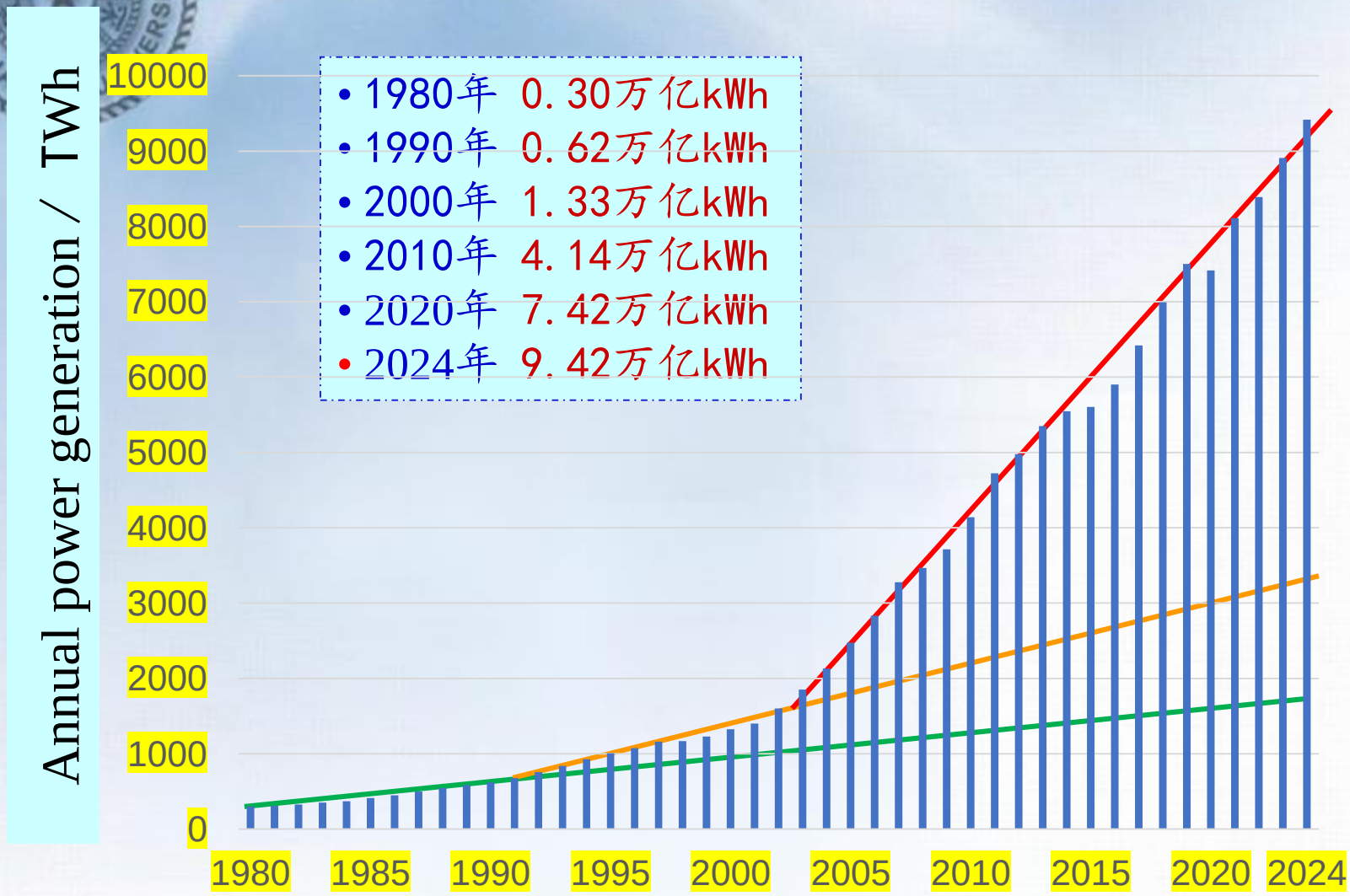
  Supporting the national economy (ensuring the development of other industries), optimizing national resource allocation, and improving quality of life

- **Changes in the focus of the power industry :**

  Long term power shortage, optimized resource allocation, energy conservation and CO_2 emission reduction, huge wind/PV power connecting,
  new type power system (driven force of development, impact on oneself and other industries, impact on future society)

Basic demand and total quantity, power grid and voltage, power structure and consumption, focus shift and CO_2 emission reduction pressure, development

2. Current situation and prospects of China's power industry



Annual power generation in China: 1980-2024
(excluding Hong Kong, Macao, and Taiwan)

2. Current situation and prospects of China's power industry

The installed capacity and annual power generation

Annual power generation:

- In 1996, surpassed Japan and ranked 2nd in the world
- In 2009, surpassed the sum UK, France, Germany, Italy, Japan, and Canada
- In 2012, surpassed USA and ranked 1st in the world
- 9.418 Trillion kWh in 2024

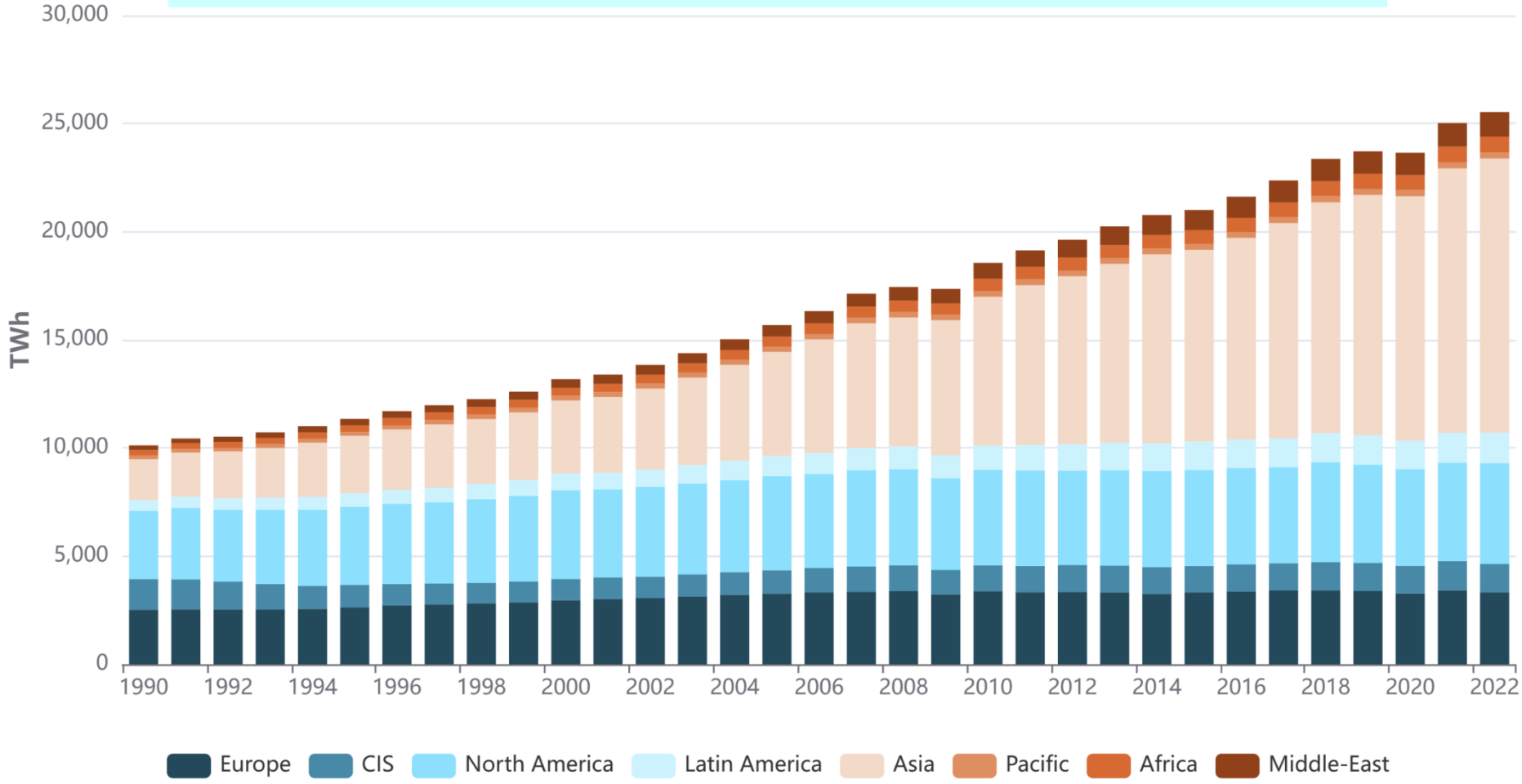
Power generation installation:

- 1987, 2000, 2005, 2011, 2019 Up to 0.1, 0.3, 0.5, 1 billion, and 2 billion kW
- 1.247 billion kW in2013, ranking the first in the world
- 1kW per capita in 2014
- 2.92 billion kW, 2kW per capita in 2023
- 3.35 billion kW in 2024

Comparison of changes in annual electricity generation between China and the US

China has surpassed the USA by a significant margin since it was only a fraction of the USA tens of years ago

Comparison of changes in annual electricity consumption On different regions of the world, 1990-2022



Power Structure and Renewable Energy Generation

The installed capacity, power generation capacity, and proportion of various power sources of power generation equipment in China in 2024

Power source	thermal power	photovoltaic	wind power	Hydro-power	nuclear power	total	non-fossil fuels
installed capacity / 0.1 billion kW	14. 4	8. 87	5. 21	4. 36	0. 61	33. 5	19. 1
Proportion / %	43. 1	26. 5	15. 6	13. 0	1. 8	100	57
Power generation / trillion kWh	6. 34	0. 42	0. 94	1. 27	0. 44	9. 42	3. 07
Proportion/ %	67. 4	4. 45	10. 0	13. 5	4. 72	100	32. 6

In 2020, coal-fired power installed capacity was 1.08 billion kW, lower than 50% of the total for the first time,

China's new energy generation > 1000 TWh for the first time from Jan.-Nov.of 2021

Non-fossil energy power generation should account for 50% -70% of the total power generation in China by 2050. There is a long way to go before reaching the peak of carbon emissions by 2030 and achieving carbon neutrality by 2060

The proportion and growth rate of national and sub industry electricity consumption in 2024

2024 China's electricity consumption (0,1 billion kWh), proportion of sub industries, and their year-on-year growth rate				
Annual consumption	primary industry	Secondary industry	tertiary industry	Life of urban and rural residents
98521 +6.8%	1357 (1.4%) +6.3%	63874 (65%) +5.1%	18348 (18%) +9.9%	14942 (15%) +10.6%

Main economic indicators of the power industry in 2024

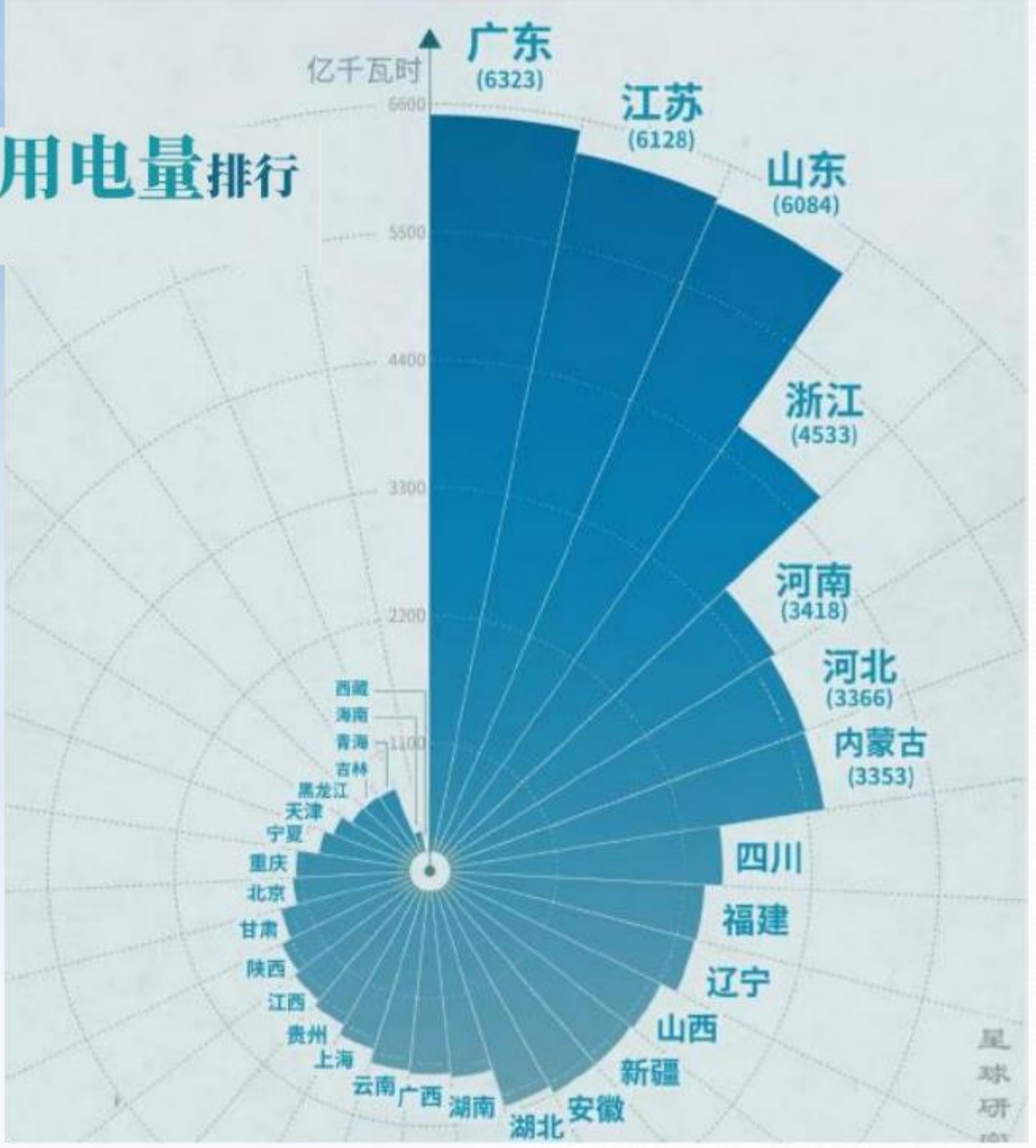
- In 2024, the investment in power industry was 1777 billion yuan, with a power supply of 1168.7 billion yuan, about 66%; The power grid is 608.3 billion yuan, about 34%. (For decades, the investment in the power grid was low, and from 2013 to 2019, the investment in the power grid exceeded that of the power source for 7 consecutive years.)

- The average utilization hours of power generation equipment nationwide in 2024 are 3442h, -157h. Coal 4628h, -62h; Hydro 3349h, +215h; Wind 2127h, -107h; PV 1211, -81h
- 2013-2023 power generation hours 4521h, 4286h, 3969h, 3785h, 3790h, 3862, 3825, 3758, 3817, 3687, 3592

- 2011-2022 Coal consumption for power supply: 330, 324, 321, 318, 315, 312, 309, 308, 307, 302.5, 301.5g/kWh
- 2024 National Grid Transmission Line Loss Rate 4.37%

2018年全国各地区用电量排行

参考资料：国资委，数据不含港澳台



The problem of uneven development among different regions still remains serious!

- In 2021, Five provinces with net output exceeding 100 TWh
- Five provinces have a power shortage exceeding 100 TWh

- In 2024, Cross regional power transmission 925TWh
- Interprovincial transmission 2000TWh

Inner Mongolia 308 TWh

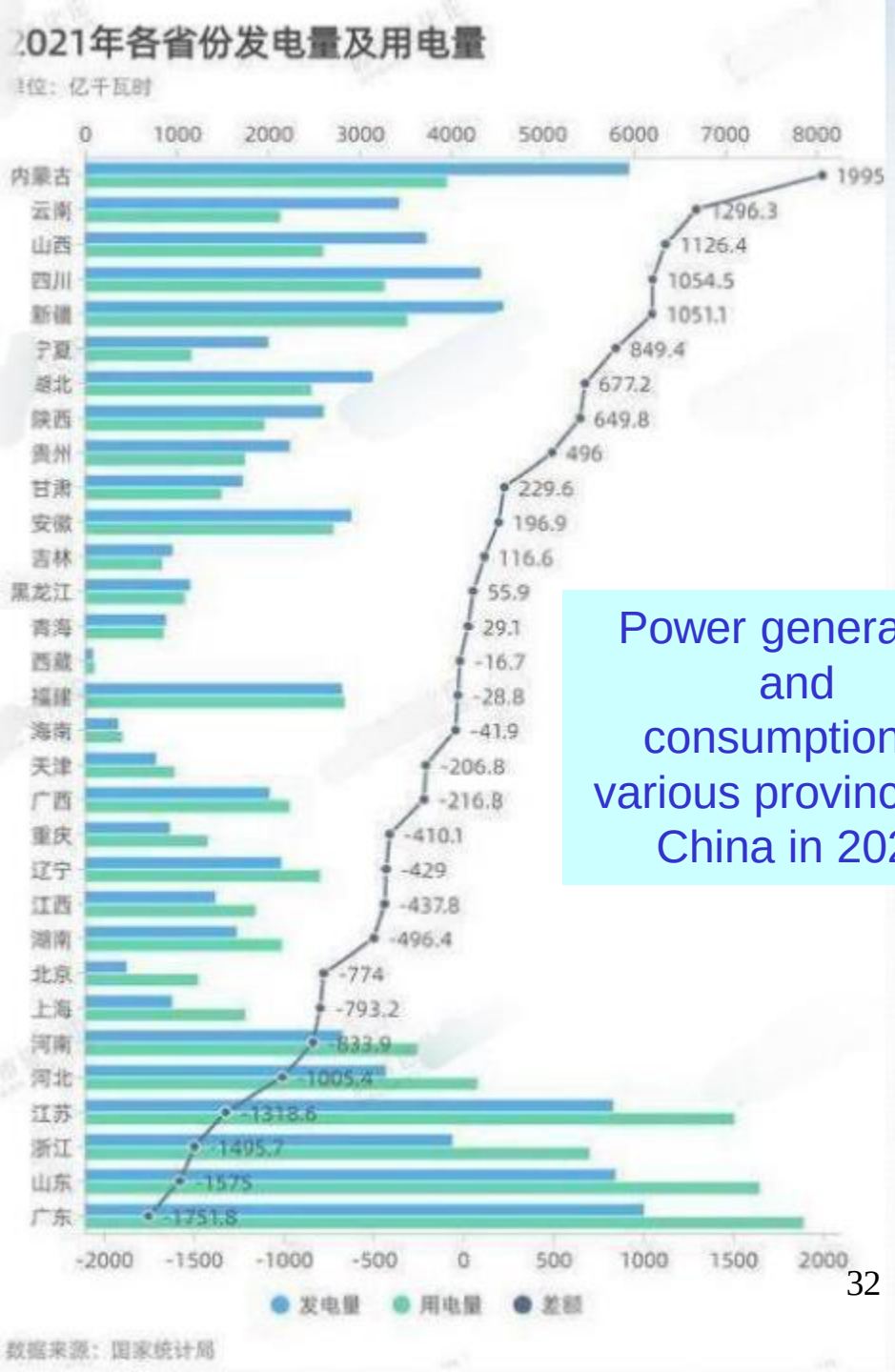
Yunnan 179 TWh

Shanxi 155 TWh

Sichuan 129 TWh

Xinjiang 121 TWh

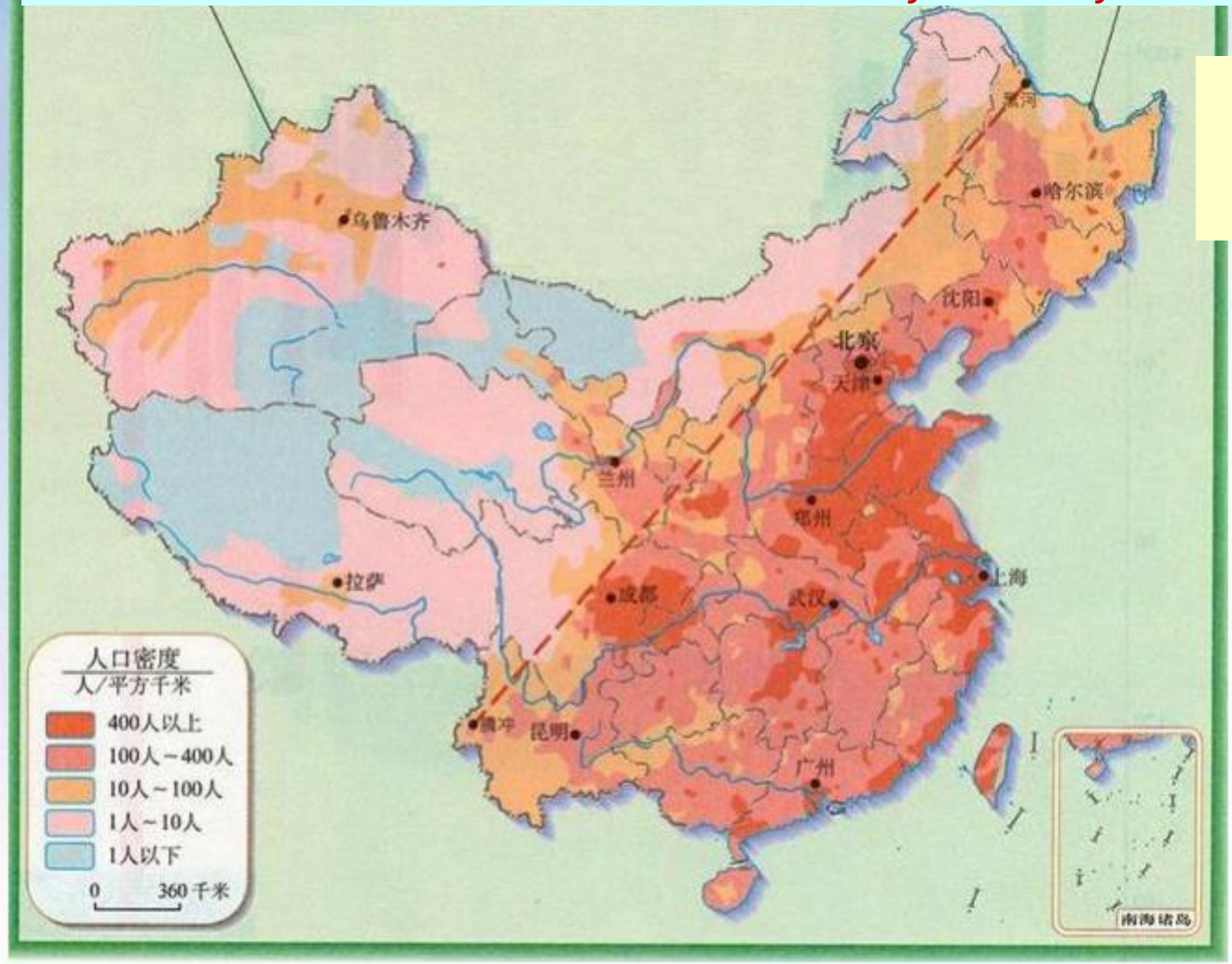
The problem of uneven development among different regions in our country remains very serious!



Power generation and consumption in various provinces of China in 2021

In the next few decades, the large-scale cross regional flow of energy and electricity in China is an inevitable trend, and the transmission distance is in scales of 500-2000 (800-3000) km. This is a basic prerequisite for considering the development direction of China's power grid.

It is expected that the electricity consumption in the central and eastern regions will still account for about 75% of the country's total by 2050



China's national conditions: basic demand for power transmission

Hu Huanyong Line:

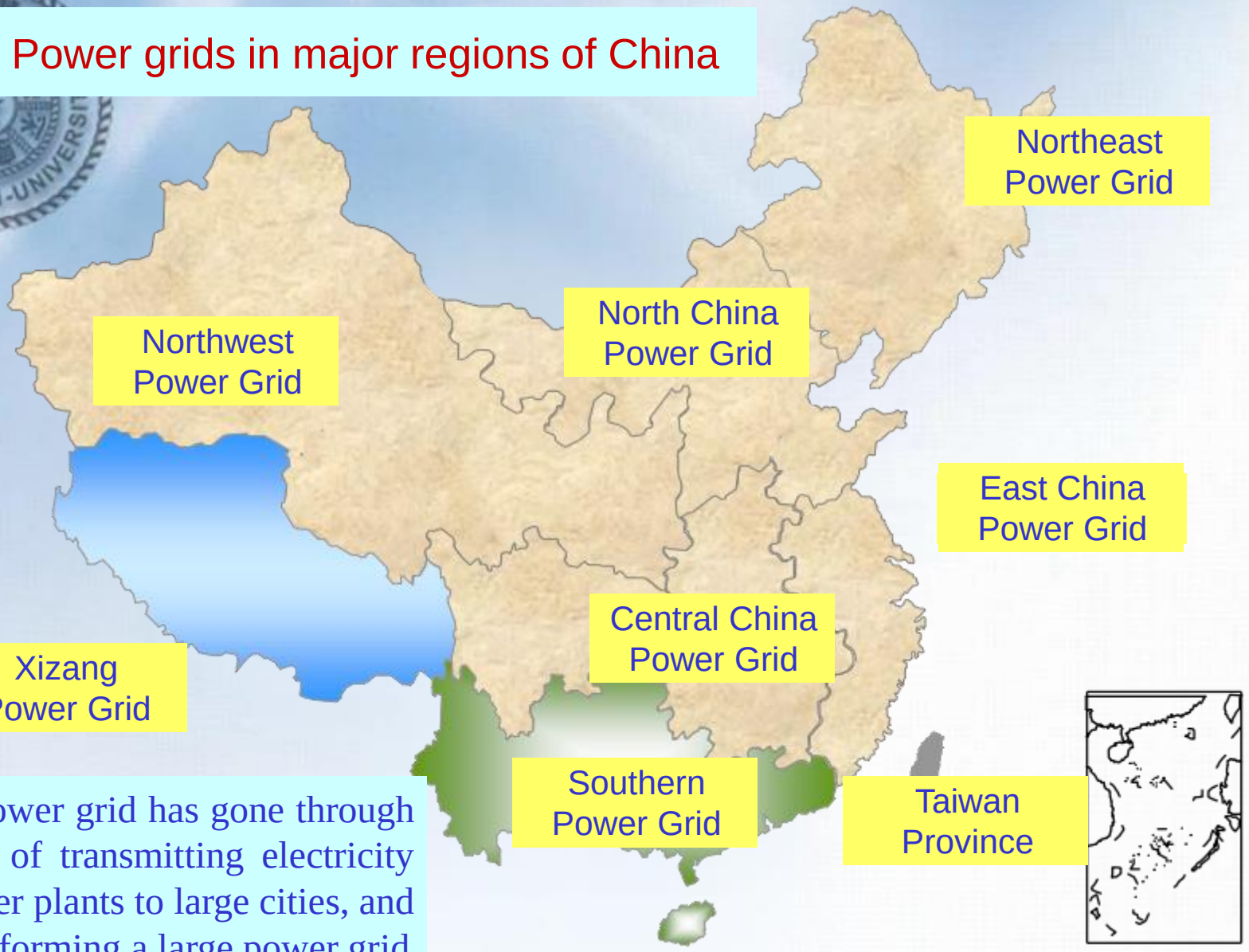
Population density dividing line

Meteorological rainfall lines

Landform division line

Cultural transformation segmentation line

Power grids in major regions of China



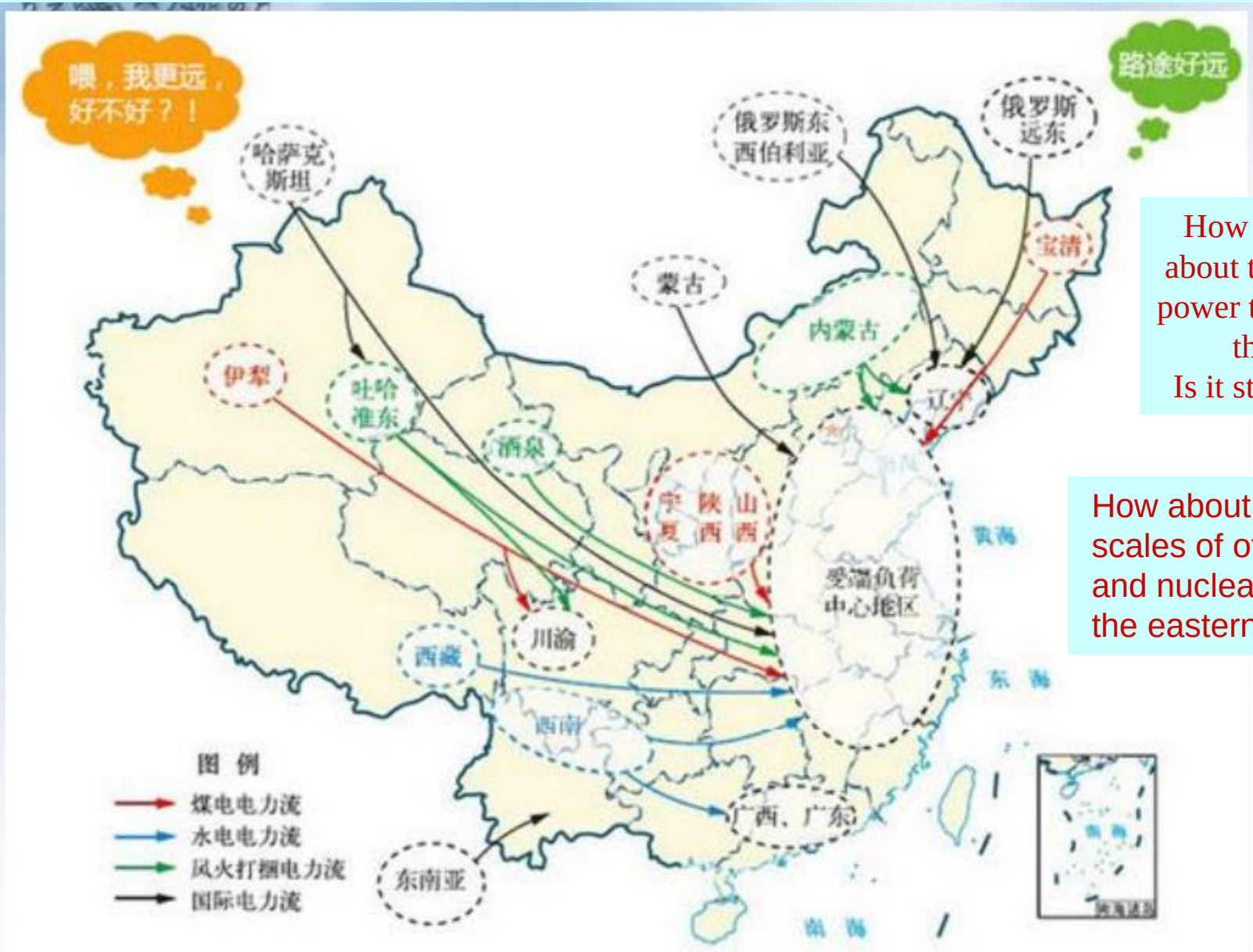
China's power grid has gone through a process of transmitting electricity from power plants to large cities, and gradually forming a large power grid

Specific Topic: Development of voltage levels in China's power grid

Seven major AC synchronous power grids in China in 2020

China's national conditions - basic demand for power transmission

Long distance, high-capacity power transmission is essential for decades!



How do you think about the demand on power transmission in the future?
Is it still necessary?

How about building large scales of offshore wind and nuclear power along the eastern coast?

Voltage level, power grid structure, and power transmission lines

Current voltage levels in China:

AC: 1000kV/500kV / 220kV / 110kV / 35kV / 10kV

Northwest Power Grid: 750kV/330kV / 220kV / 110kV / 35kV / 10kV

DC: ±1100kV, ±800kV, ±660kV, ±500kV, ±400kV

The determination of voltage level is a major issue in the development of the power grid!

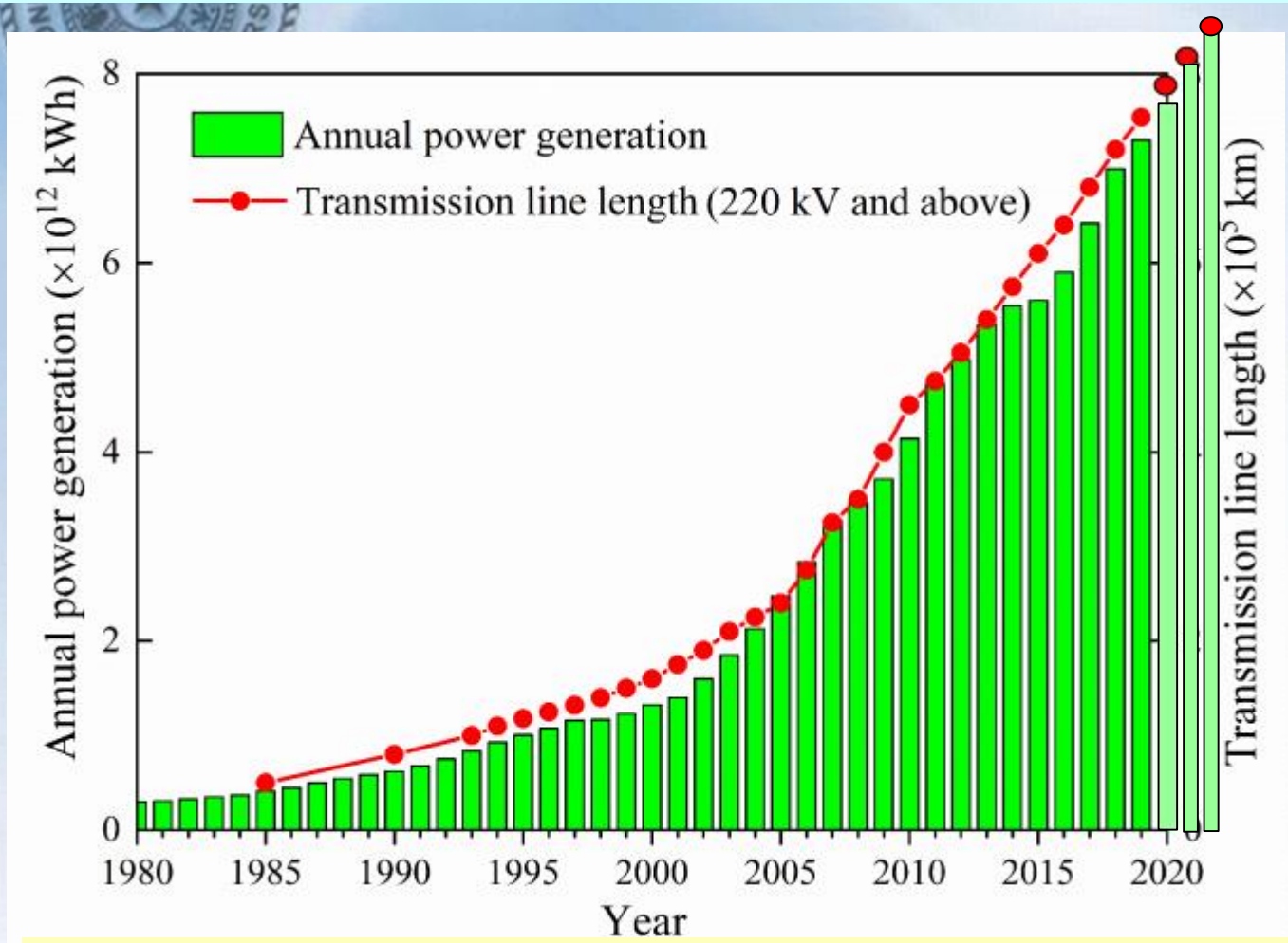
1954.1 220kV; 1972.6 330kV; 1981.12 500kV;

2005.9 750kV; 2009.1 1000kV

Specific Topic:

Development of voltage levels in China's power grid

The growth of the length of OHLs and power generation in China



-OHL for voltages of 220kV and above in 2020, 2021, and 2022: 79.4, 82.6, and 847000 km

-In 2018, the length of 35kV and above power transmission lines was 1.89 million km

-2017 10kV line : 4.43 million km

In 2019, China's highways exceeded 140000 km, and in 2013, it surpassed the United States, ranking first in the world

In 2020, China operated 37900 km of high-speed railways, accounting for more than 2/3 of the world's total

HV power T&D equipment

- power T&D equipment is the material foundation of the power industry. Over the past forty years, China's electrical equipment manufacturing industry has timely seized opportunities and achieved rapid development;
- On the contrary, the significant improvement in the manufacturing level and capability of power T&D equipment has also strongly supported the development of China's power industry (Made in China supports Made in China)
- In the past four decades, China new produced power generation increased from tens of GW to hundreds of GW per year (430GW in 2024)
- The technical level, localization rate, and competitiveness of power T&D equipment have become the highest among the three major equipment manufacturing industries in China (power T&D, metallurgy and mining, and petrochemical)

Specific Topics: Various HV power T&D Equipment

Focus Changes in Different Periods:
From Long Term Electricity Shortage to Environmental Pressure

(2006) the highest temperature in East China generally rose to 37-39℃, and the demand for electricity continued to rise. On August 14th, the peak load of East China Power Grid exceeded 106.61 GW. The electricity load has approached the maximum available power supply capacity

(2007) On July 31, at 20:45, the electricity load of the Central China Power Grid exceeded the 70 GW mark for the first time, setting a new record of 70.43 GW

(2008) On July 23, the highest electricity load in Shanghai reached 21.97 GW. The maximum amount of electricity available for local and non local use in Shanghai is only 22 GW

(2008) On July 22, during the heatwave, the power regulation loads of the Southern Power Grid and Guangdong Power Grid both reached new highs, with the highest loads reaching 83.48 GW and 56.7 GW

(2013) the East China Power Grid experienced multiple rare continues high temperatures, heavy load power supply, and UHV project construction. The highest electricity load broke historical records 12 times, reaching 209 GW, +13.3% to 2012. The electricity load in Shanghai, Jiangsu, Zhejiang, Anhui, and Fujian all reached historic highs. Among them, Shanghai 29.36, Jiangsu 77.48, Zhejiang 54.52, Anhui 26.58, and Fujian 27.98 GW.

Focus Changes in Different Periods: From Long Term Electricity Shortage to Environmental Pressure

(2013) On 2013.12.26, the highest electricity load in China reached 73.46 GW, 9% higher than the highest electricity load in 2012, setting a new record for winter electricity load in previous years.

(2017) the load of the Shanghai power grid reached a new historical high for the third time. On August 7th, 13:20, the electricity load in Shanghai reached 32.68 GW, with 15.55 GW of electricity received from outside the Shanghai power grid. The output of local units was 17.14 GW, and there was ample reserve for rotation

(2020) In the southern region affected by the strong cold air in mid December 2020, a blue warning for a cold wave continued to be issued. Power supply shortages have occurred in Hunan, Zhejiang, Jiangxi and other regions, and many have implemented long-awaited power rationing models, attracting widespread attention

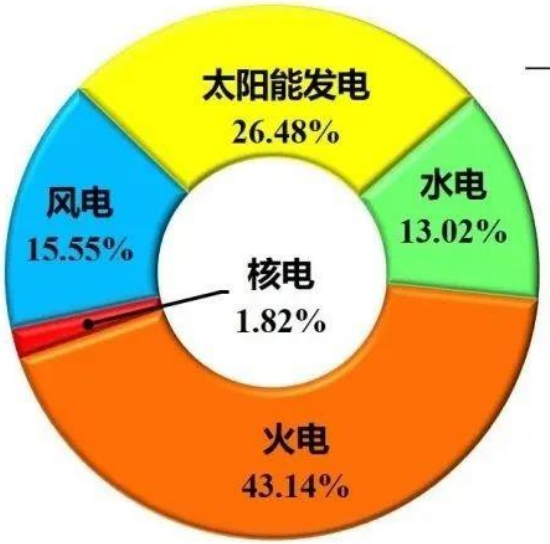
(2020.11) National Energy Administration ask wind/PV renewable energy connecting to the grid as much as possible. The Ministry of Finance publish file of subsidies for 5.95 billion Yuan. More than 20 provinces require energy storage for renewable energy.

(2021) On Jan.7, the Shandong power grid load broke the winter historical record for the 13th times, reaching 88.62 GW. Shandong power grid receives up to 18.05 GW of external power, 22% of the total power load, which enabled the Shandong power grid to smoothly overcome multiple rounds of peak electricity consumption.

Focus Changes in Different Periods: From Long Term Electricity Shortage to Environmental Pressure

(2021, Autumn) many places have implemented long-awaited power rationing modes, which are more severe than 2020 and have triggered profound reflection

(2022.11) National Energy Administration ask actively promote more renewable energy connecting to grid earlier



Left: Proportion of installed power generation capacity by 2024

Right: Proportion of 2024 new installed 0.43 billion kW

(2025.2.9) National Development and Reform Commission: promote all electricity from wind/PV into market. It's price will be decided through market transaction. It is completely different from the former benchmark pricing mechanism since 2006

Old trouble slow down, new troubles become more severe

- The “old trouble” of “power shortage” that impede Chinese economy for forty to fifty years has gradually eased finally.

In 1998, China bid farewell to the shortage economy overall, and only after 2009, the power shortages was truly avoided.

Long term “pay more attention to power generation, less attention to transmission, and no attention to consumption ”, resulting in low investment in the power grid for several decades.

In 2009, the first investment in the power grid was higher than that in power sources. From 2013 to 2019, the investment in the power grid exceeded that of the power source for 7 consecutive years.

Old trouble slow down, new troubles become more severe

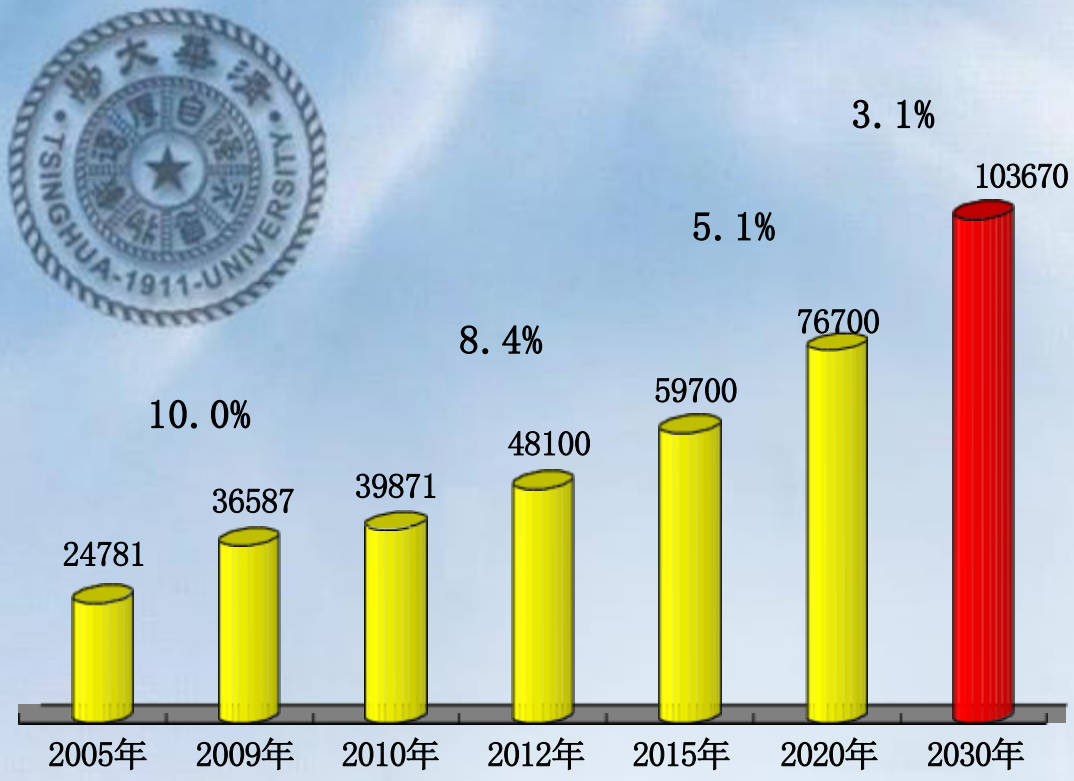
- CO_2 emissions reduction becomes a *new prominent issue*

  and environmental pressure has increased dramatically!

  Especially before the new goals of peaking carbon emissions by 2030 and achieving carbon neutrality by 2060, there is enormous pressure!
- Huge wind/solar power connecting to grid brings *big impact to power system*

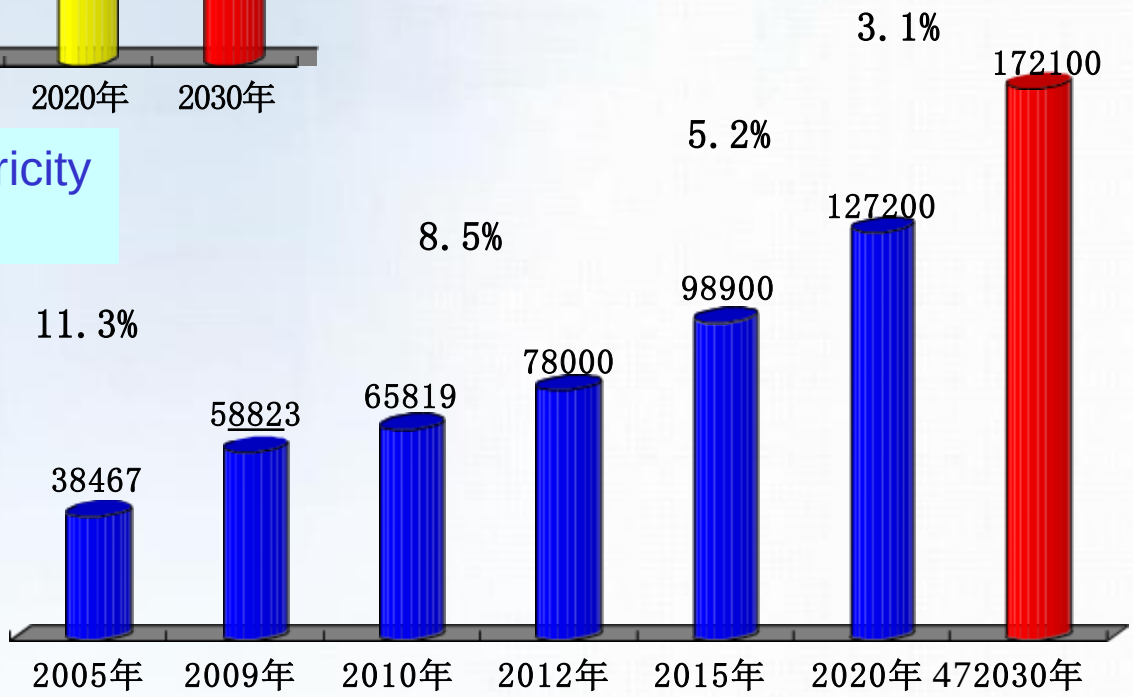
China is facing dual pressures of energy, environment, and economic development. In 2014, the central government proposed the strategic idea of energy revolution, which set a guiding goal for the future development of energy in China. In 2017, it is further clarified that the core goal of China's energy revolution and transformation is to build a new generation of clean, low-carbon, safe and efficient energy system. (A comprehensive energy system centered on electricity)

- Significantly increase the proportion of clean and renewable energy generation in total power generation
- Significantly increase the proportion of coal used for power generation in coal consumption
- Significantly increase the proportion of electricity in end-user energy consumption



Prediction in 2010, the total electricity consumption (0.1 TWh)

2010 estimate:
By 2030, the installed capacity will be 2.3 billion kW, with 1.6 kW per capita;
The electricity consumption reached 10.4 trillion kWh, 7000 kWh per capita.
Peak load of 1.72 billion kW.



Prediction in 2010, the peak load (10MW)

Prospects for China's power industry

To transition from present to a moderately developed country, it has to significantly increase the proportion of electricity utilization in final user side. China's power industry will still have great development in the coming decades.

Large capacity power transmission acrossing long-distance remains a long-term major demand in China's energy and power industry

- How to ensure the stable operation of large scale AC/DC hybrid power systems
- How to ensure the security and reliability of large capacity & long-distance power transmission
- How to ensure the effective consumption of large capacity and high proportion renewable energy

It has been the top priority of China's power system for many years,
and is an inevitable requirement for building a new type of power system

China is facing dual pressures of energy environment, and economic development. It is a huge challenge that the energy/power system has to face: How to solve the transformation towards clean energy and achieve the mutual conversion, large capacity storage, and efficient utilization of multiple types of energy on a larger scale.

National demand, industry development, and personal professional career space

High Voltage Engineering

Introduction

1. The development of HV power transmission
2. The current situation and prospects of China's electric power industry
3. Special issues under high voltage & high electric stress
4. Special phenomena under HV and their applications

1. Development of High Voltage power transmission

2. Current situation and prospects of China's power industry

3.Special issues under high voltage and high electric stress

From the perspective of curriculum teaching

HV insulation, HV testing, overvoltage prevention and protection

Power T&D equipment (including lines and power stations)

Material selection, structural design, manufacture, testing, and inspection during operation and maintenance

4.Special phenomena under high voltage and their applications

From the perspective of engineering applications

How to Bridge the Gap between Industry and Universities?

3.Special issues under high voltage and high electric stress

- HV insulation: High voltage and insulation - similar to "spear and shield"
  (Involving insulation materials and insulation structures)

- What are the different characteristics or behavior of insulation materials under HV compared to low voltage ?
- How does HV go through the grounded space (house, equipment), minimize the size?

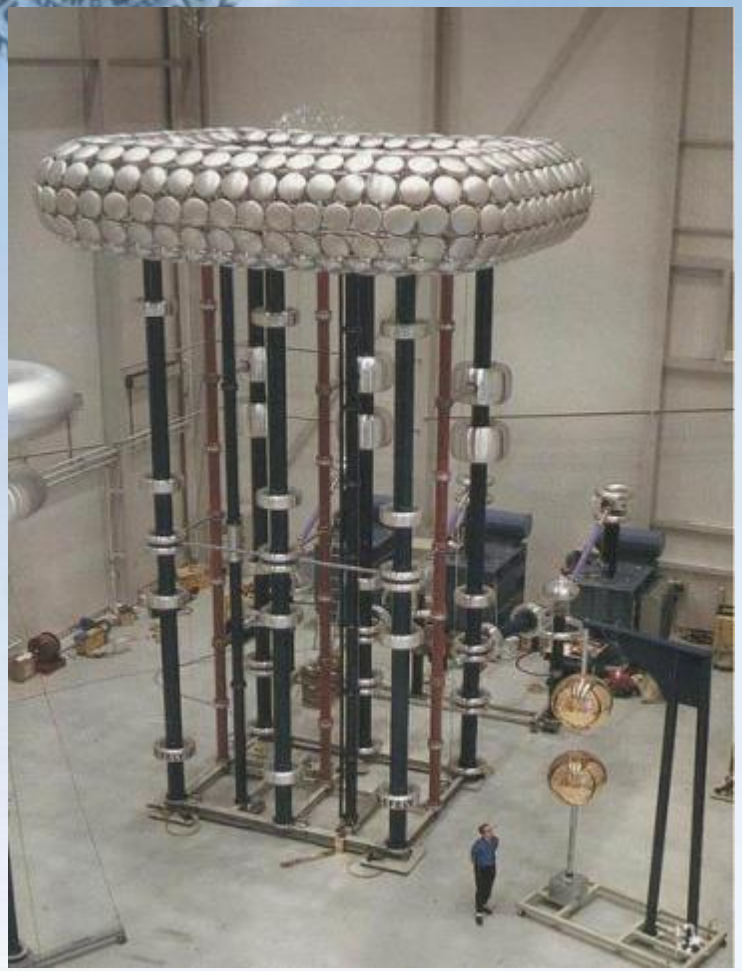
- What is the difference in insulation performance between AC and DC? What to do with insulation under high electric stress?
- How to choose appropriate materials, design appropriate structures, and achieve the functionality of HV equipment at a reasonable price?
- Are there any better materials? How does the progress in the field of materials promote electrical engineering?

- Can power lines and equipment operate reliably in various weather conditions?
- Can it operate reliably for a long time? Is maintenance needed?
- Is the entire process (manufacture and operation) environmentally friendly?
- ……

3.Special issues under high voltage and high electric stress

- **HV testing technique:** the research means and testing methods

  - How to generate different types and magnitudes of required HV? How to measure HV?
  - What effective means and methods are used to quantitatively study the phenomena or the performance of equipment under HV?
  - How to conduct HV tests on electrical equipment? How high is the voltage that equipment bears during operation and testing?
  - Is the HV test conducted on the equipment equivalent to the result under long-term operation?
  - How do you know the performance is qualified after production? Can it still be reliable after several or tens of years of long-term operation?
  - Is the measurement result accurate under HV and high electric stress?
  - What can be learned from new sensing technologies?
  - How to achieve device intelligence under the Internet of Things or Energy Internet?
  - ……



Indoor and outdoor high-voltage testing equipment

3.Special issues under high voltage and high electric stress

- Overvoltage and its protection:

  - How high is the voltage in power system? When and where the highest voltage appears?
  - Is lightning the biggest threat? Can it be completely prevented and protected?
  - What causes overvoltage? Is there any way to reduce it?
  - Does electrical equipment need to rely on its own insulation to bear all overvoltage?
  - What is the insulation coordination? How to realize the technic and economic balance?
  - What are the requirements of IT manufacturing for power supply reliability?
  - ……

- Electromagnetic environment:

  - Radio interference, audible noise, power frequency electromagnetic field above ground, DC composite field
  - Electromagnetic compatibility, electromagnetic ecological effects
  - ……


2009/03/30


2009/03/30

High voltage engineering

Introduction

1. The development of high voltage power transmission
2. The current situation and prospects of China's electric power industry
3. Special issues under high voltage and high electric stress
4. Special phenomena under high voltage and their applications

Are there any other circumstances HV will play an important role ?

4.Special phenomena under high voltage and their applications

Electrostatic technology:

- Electrostatic precipitation (electric dust collection)
- Ozone preparation
- Electrostatic spray painting
- Electret
- Electrostatic spinning
- Electrostatic separation
- Printing
- Wastewater treatment (deodorization, decolorization)
- Low temperature plasma sterilization and disinfection
- Vegetable and fruit retain freshness, aquaculture, etc

4.Special phenomena under high voltage and their applications

Electrostatic technology: electrostatic precipitation, ozone preparation, electrostatic spray paint, electrostatic spinning, electret, wastewater treatment, printing, low temperature plasma sterilization and disinfection, retain freshness

Hydroelectric effect:

- sand cleaning of castings
- electric spark source (seabed resource detection, bridge pile detection)
- oil production (unblocking the blocked oil well)
- electromagnetic pulse stamping forming
- extracorporeal crushing of kidney stones

4.Special phenomena under high voltage and their applications

Electrostatic technology: electrostatic precipitation, ozone preparation, electrostatic spray paint, electrostatic spinning, electret, wastewater treatment, printing, low temperature plasma sterilization and disinfection, retain freshness

Hydroelectric effect: sand cleaning of castings, electric spark source, oil production, pulse stamping forming, and external crushing of kidney stones

Wire explosion technology:

- nuclear explosion simulation,
- spray coating of high melting point metal,
- preparation of nano powder (metal powder, metal oxide powder, metal nitride powder, carbon nano powder)

4.Special phenomena under high voltage and their applications

Electrostatic technology: electrostatic precipitation, ozone preparation, electrostatic spray paint, electrostatic spinning, electret, wastewater treatment, printing, low temperature plasma sterilization and disinfection, retain freshness

Hydroelectric effect: sand cleaning of castings, electric spark source, oil production, pulse stamping forming, and external crushing of kidney stones

Wire explosion technology: high melting point metal spray coating, nuclear explosion simulation, nano powder preparation

Low temperature plasma technology:

- material surface treatment,
- plasma stealth technology

4.Special phenomena under high voltage and their applications

Electrostatic technology: electrostatic precipitation, ozone preparation, electrostatic spray paint, electrostatic spinning, electret, wastewater treatment, printing, low temperature plasma sterilization and disinfection, retain freshness

Hydroelectric effect: sand cleaning of castings, electric spark source, oil production, pulse stamping forming, and external crushing of kidney stones

Wire explosion technology: spray coating of high melting point metal, nuclear explosion simulation, nano powder preparation

Low temperature plasma technology: material surface treatment, plasma stealth

Pulse power technology:

- electromagnetic pulse emission,
- electromagnetic pulse projectile

4.Special phenomena under high voltage and their applications

- Electrostatic technology:
- Hydroelectric effect:
- Wire explosion technology:
- Low temperature plasma technology:
- Pulse power technology:

Accurately release of energy with high energy density or high power density onto a target object and direction within an accurate time and space.

High voltage is a ideal technical means:
easy operation, accurate control, high power density, and high energy density

High voltage is the most important technical means to achieve large-scale power transmission, and it is also an effective energy utilizing means with high energy density and high power density

In the study of professional courses and future research, attention should be paid to determining the focus of attention and ways to solve problems based on their nature:

Scientific question: What concerns us is why
Technical issue: What we are concerned about is what to do
Engineering problem: concerned with comprehensive optimization

There are three types of problems in the high-voltage engineering class, please pay attention to distinguishing them when learning

Mastering scientific principles,
Knowing technical means,
Understanding engineering specifications

Welcome to the high voltage engineering course and wish you all with an active mentality!