Selected topic:

The progress of voltage level in China power grid

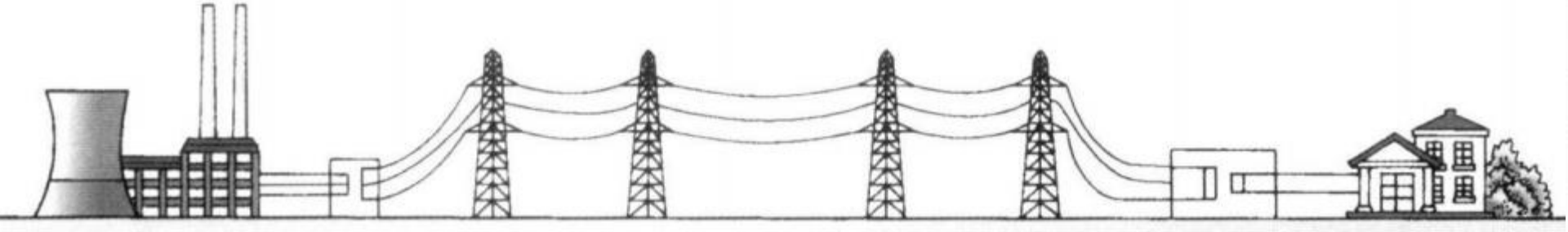
The determination of voltage level is a key issue in the development of power grid!

Thomas Edison bring us **light** **Nikola Tesla** bring us **power**

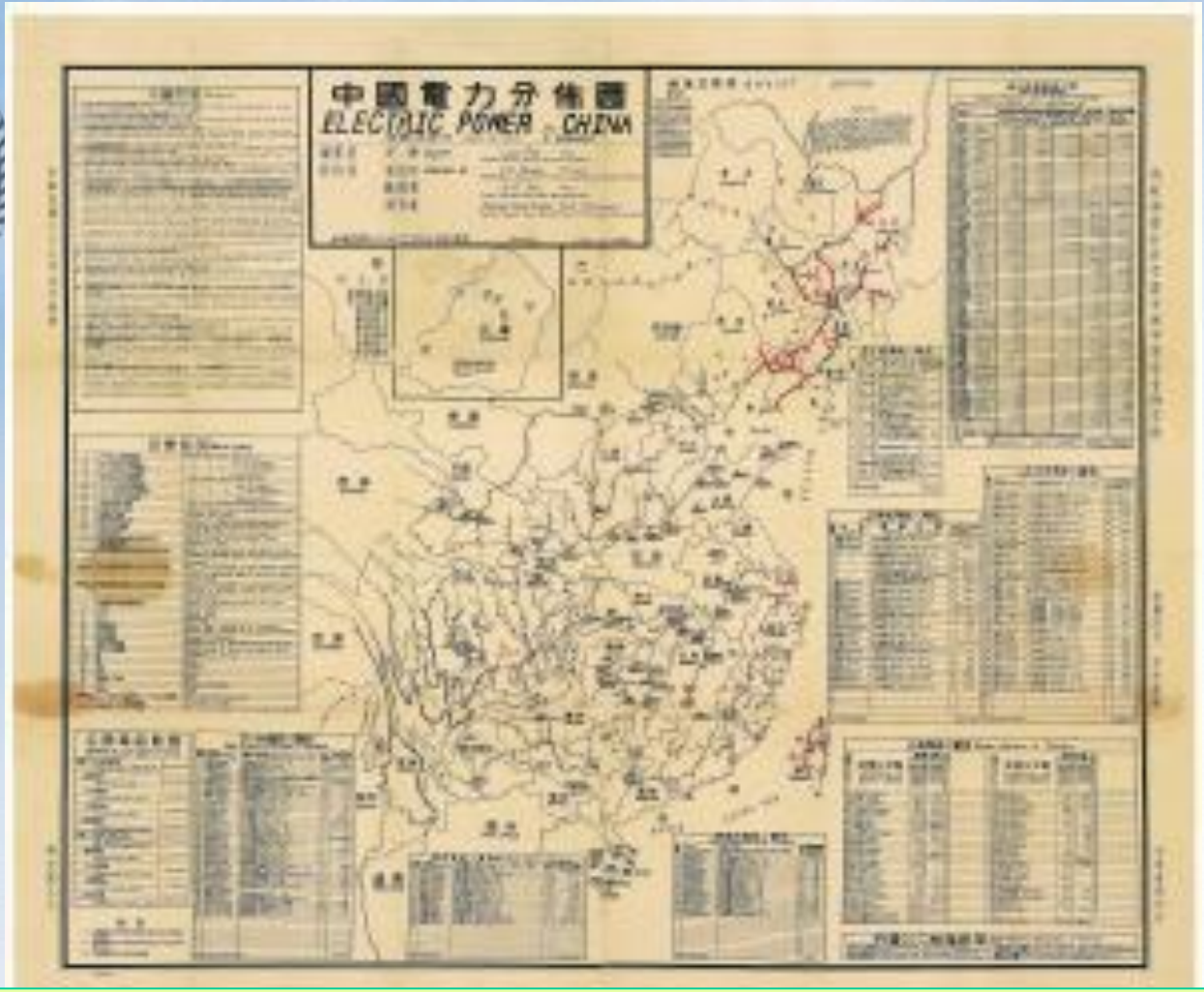
The large-scale transmission of electrical energy is the foundation for the widespread application of electrification

Whether AC or DC, high-voltage transmission is the most important technology to achieve large-scale transmission of electric energy

- Equipment with the same rated voltage within a synchronous grid is required because of networking (different voltage levels are connected from transformers in substation. T&D: transmission and distribution)
- For the purpose of standardization, the concept of voltage levels (or standard voltage sequences) arises. Easy for manufacture and maintenance
- The voltage level is the first indicator to describe the grid (voltage, installed capacity, generation/consumption, peak load, users...)
- The determination of voltage level is a key issue in the development of power grid!



power plant substation HV lines substation end user



The Map of Electric Power, China drawn on June 30, 1948, describes the distribution of electricity in China in 1948, and was issued by Zhonghua Book Company.

- The size of the full map is 85 cm ×72 cm under the ratio of 1:6,000,000. It records the distribution of electricity in China at that time in detail
- It is the first precious information to study the development of electric power at that time. It has a high historical research, aesthetic and preservation value.

- It maps all lines of electric power grid with different voltage levels, such as 220kV, 154kV and 110kV power lines in Northeast China and Taiwan province, and 77kV and 66kV power grid lines in Hebei province.

- The table of power generation capacity of each province in the map records the existing capacity, the wartime power generation capacity, the wartime destroyed capacity, and the current available capacity.

- At the same time, it also records the details of thermal power plants, hydroelectric power plants and water resources, and classifies rivers above 1000 to 20,000kW per kilometer of power generation, using corresponding symbols to identify different river segments, which is an indispensable historical data for the study of thermal and hydroelectric power generation in China.

- In order to reflect the historical background of electric power development, the map describes the operation mode and generation capacity of power plants from two dimensions: historical and parallel.

- There were two modes of power plant operation: state-owned and foreign. State-owned including public and private, public including state, provincial, city, county and government agencies operating; Private enterprises refer to private enterprises, joint ventures between government and businessmen, and joint ventures between Chinese and foreign countries. Foreign capital refers to the operation of foreign capital.

- In 1937, the country's total power generation capacity was about 631,165kW. The state-owned power generation capacity was 355,870kW, and the foreign-funded power generation capacity was 275,295kW, which were similar.

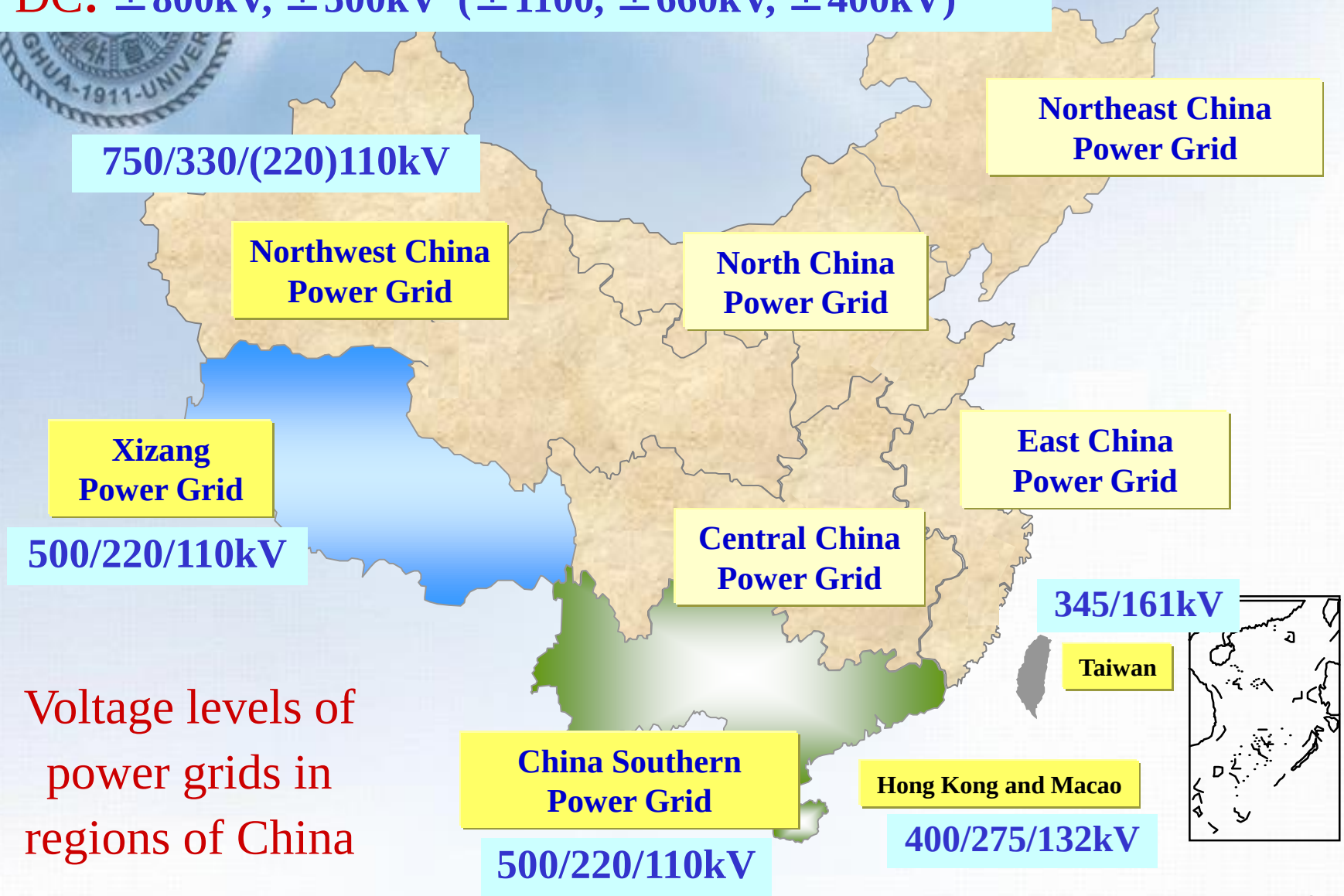
- In 1947, the national power generation capacity doubled to 1,441,878kW, and the national power generation capacity accounted for about 82% of the country, reaching 1,177,378kW, which has far exceeded the foreign power generation capacity and become the main body of China's power industry.

- The hand-drawn was in both traditional Chinese and English, and the font is standardized, neat and orderly, which is impressive.

- The chart is compiled by British economic and technical expert Peter Lian; The editors are Bao Guobao, the pioneer of China's modern power industry and the director of the General Administration of Electricity Industry of the Ministry of Fuel Industry of the Central People's Government in 1950, Yang Jianchu, one of the founders of industrial electrical automation, and Zhou Zonglian, an engineer of North China Water Resources Commission.

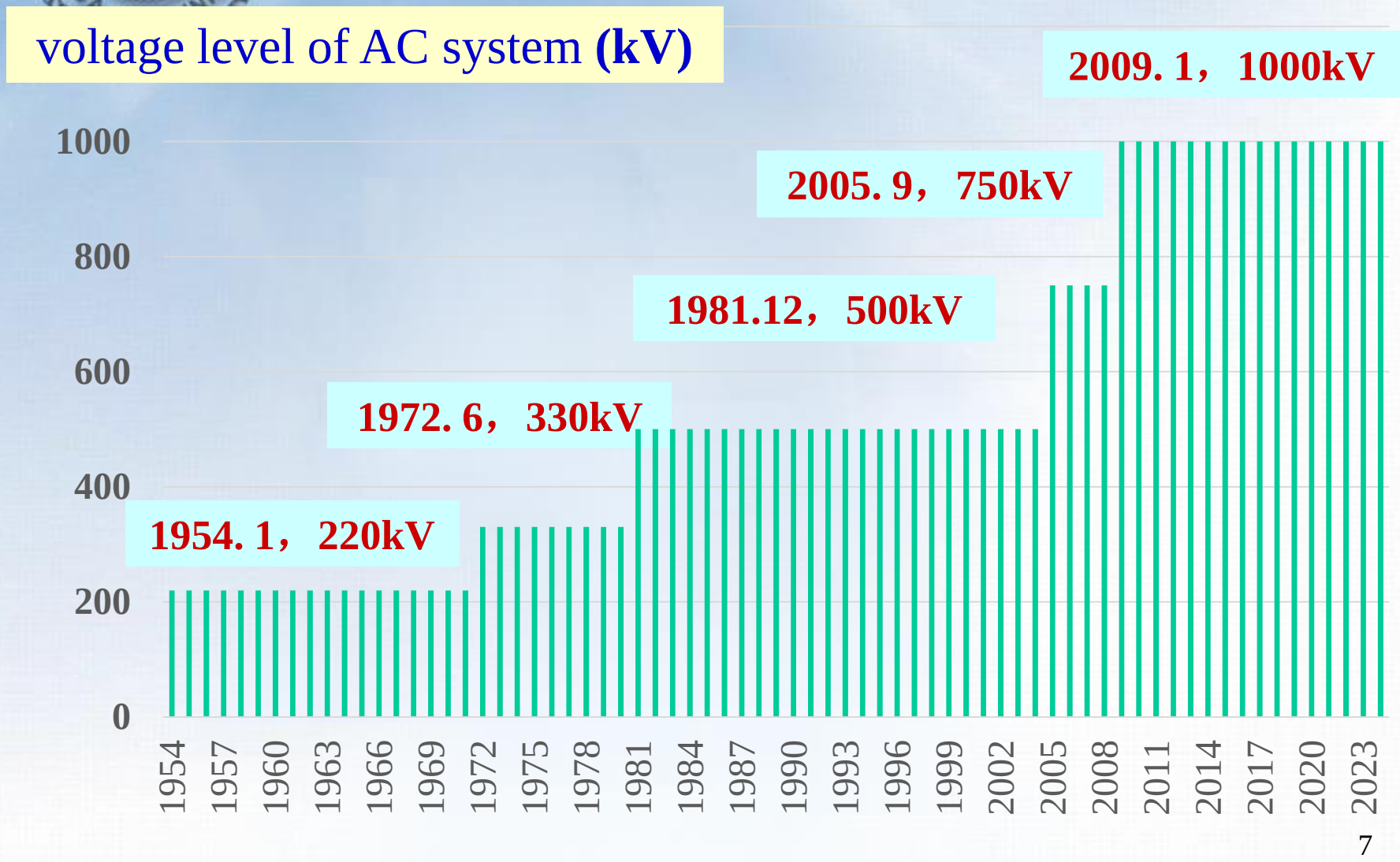
AC 50Hz: 1000/ 500 / 220 / 110kV

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



Voltage levels of power grids in regions of China

The increase of voltage level of AC system in China



The increase of voltage level and the development of power grid

- 1950s to 1970s: focus on construction of 110-220kV local power grid, transmit power from local power plants to the city and the provincial network.

In 1972, the first self-designed and constructed 330kV Liu-Tian-Guan project was put into operation (Liujiaxia Hydropower Station – Tianshui - Guanzhong Tangyu Substation, 534km, designed as 420MW).

In 1981, the first 500kV Pingwu Line was completed and put into operation (Pingdingshan Yaomeng Power Plant – Jingmen - Wuchang Fenghuangshan Station, 595km, designed as 1000MW).

Started the inter-provincial networking.

The increase of voltage level and the development of power grid

- 1980s to 1990s: large-scale 500kV power grid construction, provincial power grid formation, and cross-provincial power grid began in the large region.

In the late 1980s, six inter-provincial power grids were initially formed in Northeast China, North China, Central China, East China, Northwest China and South China and six provincial grids in Fujian, Shandong, Sichuan, Hainan, Xinjiang and Xizang (with 330kV as the backbone in Northwest China and 500kV as the backbone for all other regions).

In 1989, ±500kV Gezhouba-Shanghai DC transmission project was completed, 1046km, 1200MW, Central China - East China cross-region DC network

The increase of voltage level and the development of power grid

- Three Gorges began 500kV national networking: 1997-2007 Three Gorges big power project.

  More than 9,000 km of 500kV AC and DC OHLs in total.

  Several large capacity long-distance HVDC transmission project.

  Is it possible to choose 1000kV UHVAC at that time?

2001 - 2005, North - Northeast, East - Fujian, Sichuan - Chongqing - Central China, Central - North China, Central - South China, Shandong - North China, Northwest - Central China AC or DC interconnection.

Sept. 2005, 140km 750kV Guanlan Line (Guanting - Lanzhou East) put into operation, step up to the level of 750kV.

The increase of voltage level and the development of power grid

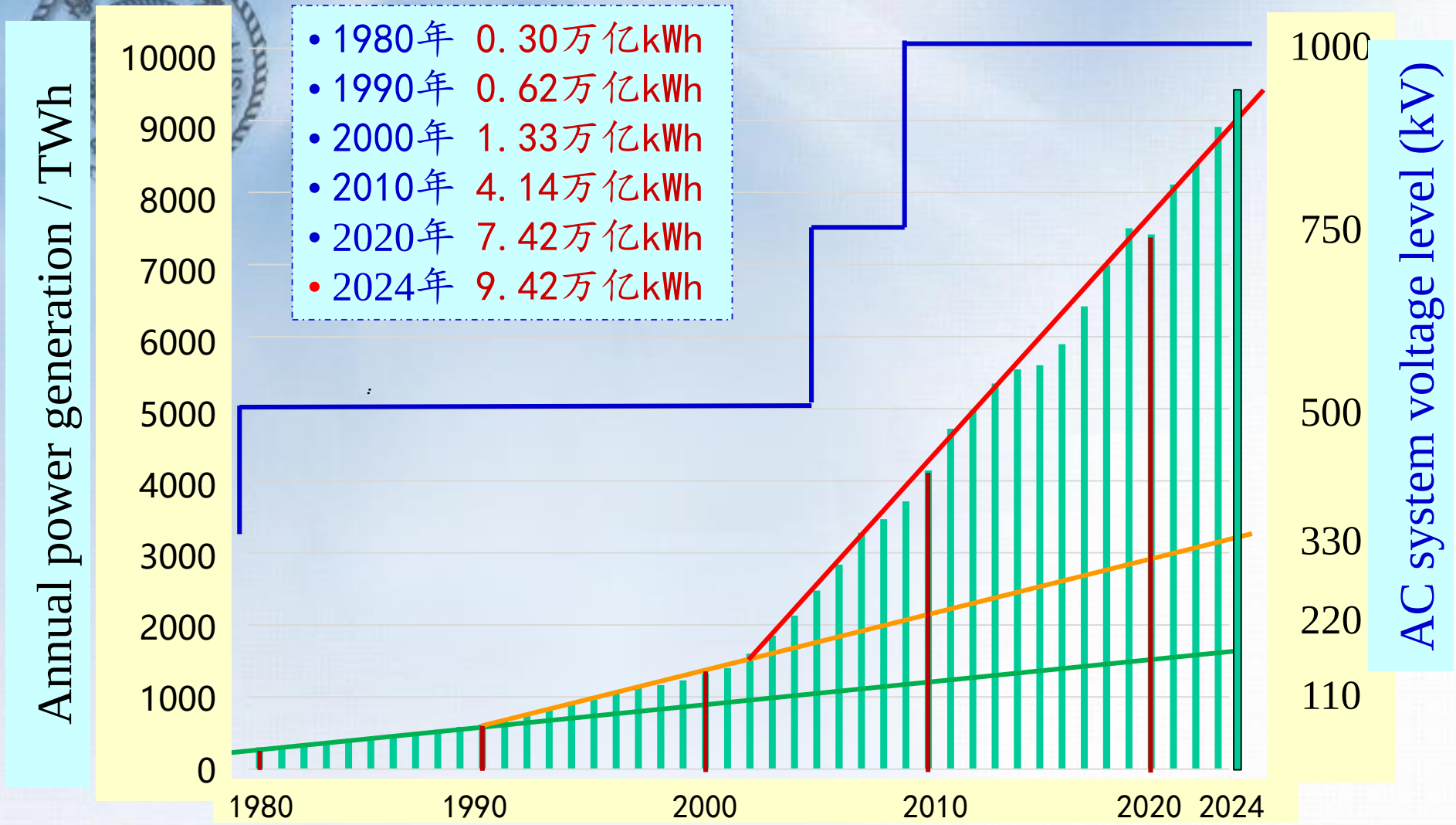
- Since 2009, UHV:

Jan.6 of 2009, Jindongnan - Nanyang - Jingmen 654km 1000kV UHVAC

In 2010, Yunnan-Guangdong 1417km 5GW, Xiangjiaba-Shanghai 1906km 6.4GW, in 2014 Mami-Zhengzhou 2192km 8GW ±800kV UHVDC bipolar projects put into operation

2018-2019, Changji-Guquan 3340km ±1100kV UHVDC bipolar operation

(2011 Ningxia-Shandong ±660kV, Qinghai-Xizang ± 400kV DC operation)



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

The principle of voltage level selection

- According to the electricity demand of economic scale, power consumption, power supply reliability, current grid voltage level etc., to determine the grid structure, power supply capacity, transmission distance, number of transmission circuits, transmission capacity of each line, then determine the voltage level of a new transmission line before construction.

- According to the estimation of power consumption demand and new power supply capacity in the future years, and according to the maturity of the equipment with higher voltage level, to determine the higher voltage level for the entire grid in the future.

- The determination of a new voltage for a new line means to determine voltage level for the entire grid for tens of years in the future.

The principle of voltage level selection

When to build a new line with higher voltage level? Choose which voltage value?

- If the new voltage is selected too low, it will soon be unable to meet the demand of transmission capacity, and face the demand for higher voltage again, resulting in a lot of waste.

- If the new voltage is too high, the equipment maturity will be very poor, the power supply reliability of the system is too low, and the comprehensive social cost is still too high.

- The specific emerging time of new voltage levels in the past often depends on the construction of a large power source, say huge hydropower plant in China. Generally, a single line was constructed firstly, and then gradually developed to the entire grid with higher voltage level.

The principle of voltage level selection

According to the past experience, the economic scale will be double and redoubled in circa 20-30 years of development. At the same time, the demand for electricity increased by 4-5 times, then a new voltage level should emerge.

The development and maturity of a new voltage level also takes about 20-30 years.

Therefore, the ratio of new voltage level to the original one is roughly 2 (1.7-3). That means the voltage is doubled and the transmission capacity is about 4 times of the original voltage level.

A reasonable voltage sequence is gradually formed based on worldwide experience

- 110～165 / 220～245 / 330～400 /735～765(800) / 1500
- 110～165 / 220～245 / 500 / 1000～1150(1200)

Is it better to **select only one line of voltages, and select one voltage from each grade**, rather than using all voltages!

China's current voltage level of power transmission, distribution and power supply

- AC:

North China, East China, Central China, Northeast power grid:

1000kV / 500kV / 220kV / 110(66)kV / 35kV / 10kV / 400V

Northwest Power Grid:

750kV / 330kV / (220kV) / 110kV / 35kV / 10kV / 400V

China Southern Power Grid:

500kV / 220kV / 110kV / 35kV / 10kV / 400V

- DC (excluding flexible DC):

±1100kV, ±800kV, (±660kV), ±500kV, (±400kV)

(DC usually only refers to single project instead of the system voltage level)

(Electrified railway contact network: AC 25kV single phase)

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

Voltage level of distribution network in China

Since the 1950s - 1960s, the voltage of the urban distribution network has been gradually unified to 10kV.

With the expansion of the capacity and coverage of power supply, the distribution voltage level has been continuously improved, gradually increasing from 35kV to 110kV, and even 220kV in a few megacities.

China‘s distribution voltage level has become：(220kV) / 110kV / (35kV) / 10kV

Transmission grid and distribution network are divided by their functions, but not only by their voltage

Beijing has abolished 35kV in urban areas and retained 35kV in suburban areas.

The 10kV power supply radius is generally 1-1.5km, and the power supply capacity is 10,000kW. 380V can only supply within 100-150m.

Suzhou Singapore Industrial Park adopted 20kV voltage and the effect is very good.

Selection of voltage level of distribution network

It is necessary to comprehensively consider the factors including long-term planning of the city, saturated power supply load, load density, reliability, power supply loss, etc.

The overall principle is to simplify voltage levels and increase the voltage of the distribution network (such as 20kV, especially in the construction of new urban areas.

In China, 20kV equipment and conductors are only within 120% of the price of 10kV, which is not too expensive.

However, the problem of voltage level of distribution network is often ignored.
In the past 30 or 40 years, China has built a huge number of infrastructure, but the voltage of the distribution network has not been improved.

What are the requirements for the voltage level of the distribution network when distributed renewable energy is connected to the distribution power grid?

How should the voltage levels of new power systems be considered in the future?

In 2008, the State Grid Corporation of China started the optimization study of transmission and distribution voltage level (sequence)

1000kV 500kV 220kV 110kV 35kV (20kV) 10kV 0.4kV

In the sequence above, how to simplify further? Which voltage to cancel?

is

1000kV 500kV 220kV 110kV 10kV 0.4kV

or

1000kV 500kV 110kV 20kV 0.4kV

or

1000kV 500kV 220kV 20kV 0.4kV

110kV lines are currently the most common and have the largest proportion

Northwest grid canceled 220kV in previous years, and changed to

750 / 330 / 110 / 10 / 0.4kV

Substation and supply voltage of Tsinghua campus

- Double circuit 110kV incoming line after 1986
- Tsinghua substation step-down transformer 110kV/10kV then 10kV distribution grid in Tsinghua campus
- Transformer 10kV/380V(220V) in each buildings

Before 1986, 35kV/10kV, with one transformer of 3200kVA

In 1986, new substation, uprated to 110kV/10kV, 2×8000kVA transformer

In 2000, uprated transformer to 110kV/10kV, 2×32000kVA

In 2002, uprated transformer to 110kV/10kV, 2×50000kVA, one used and one standby

In 2016, uprated transformer to 110kV/10kV, 3×50000kVA, two used and one standby

(The electricity consumption of the campus increases by 15%~20% every year)