



国家电网有限公司
STATE GRID
CORPORATION OF CHINA

Renewable Energy Generation: Challenges and Practices

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State Grid Corporation of China (SGCC)

Sep 7, 2018

- 1. Developments of Renewable Energy in SGCC**
- 2. Challenges on Large-scale Wind and Solar Power Integration**
- 3. Work carried out and proposed by SGCC**

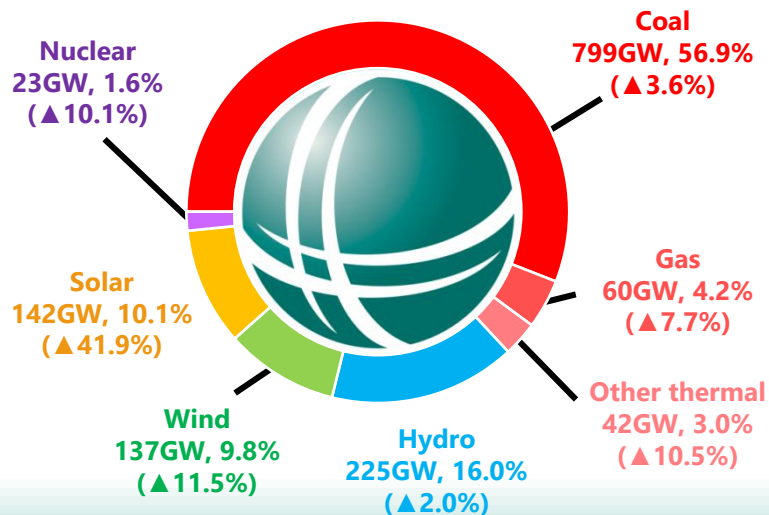
Introduction of SGCC



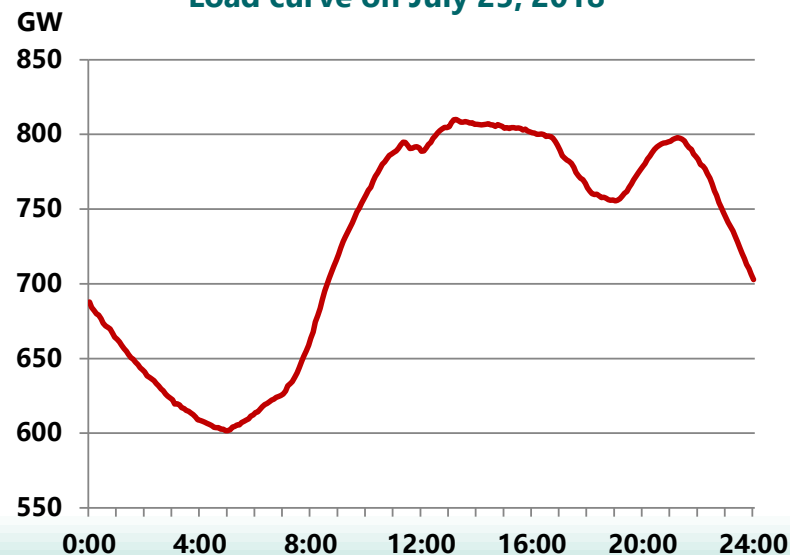
SGCC is the world's largest public utility company which serves over 1.1 billion people and covers 88 % of the Chinese territory.

- ◆ By July 2018, the total generating capacity installed in SGCC's service area had reached 1427 GW.
- ◆ The maximum load in SGCC's service area reached a historical high at 810 GW on July 25, 2018.

Generating capacity by energy source (July 2018)



Load curve on July 25, 2018

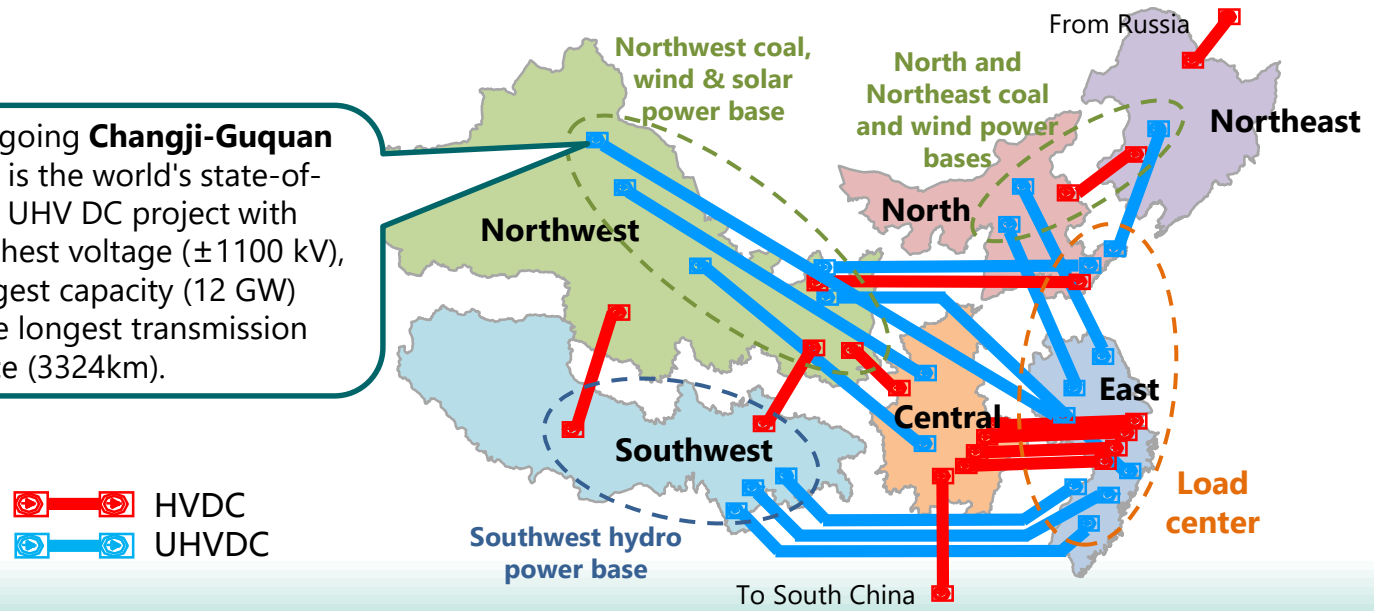


Promoting UHV Power Transmission



China's coal, wind and solar energy resources concentrate in the Three-North areas, while hydro power resources are mainly located in the southwest. However, over 70% of electrical load resides in Central and East China. SGCC actively promotes the ultra-high voltage (UHV) power transmission to facilitate large-scale, long-distance allocation of energy resources. It has constructed 11 UHV DC projects with a total length of over 40,000 km, and the interregional transmission capability exceeds 96 GW.

The ongoing **Changji-Guquan** project is the world's state-of-the-art UHV DC project with the highest voltage (± 1100 kV), the largest capacity (12 GW) and the longest transmission distance (3324km).

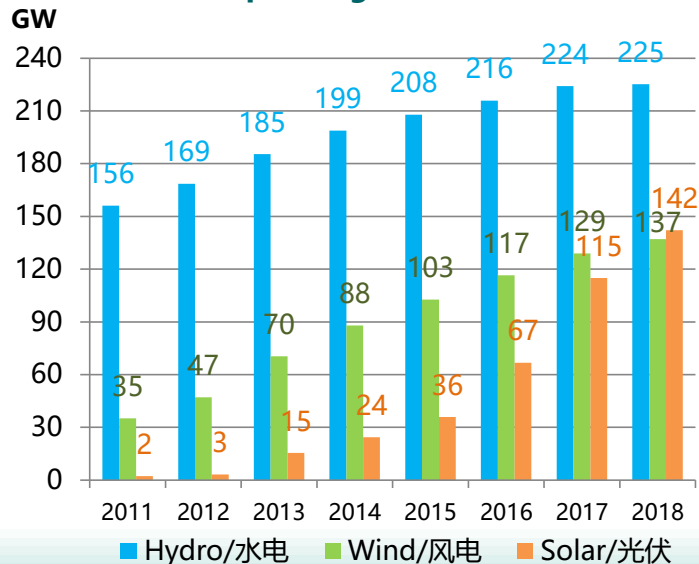


Renewable Power Generation

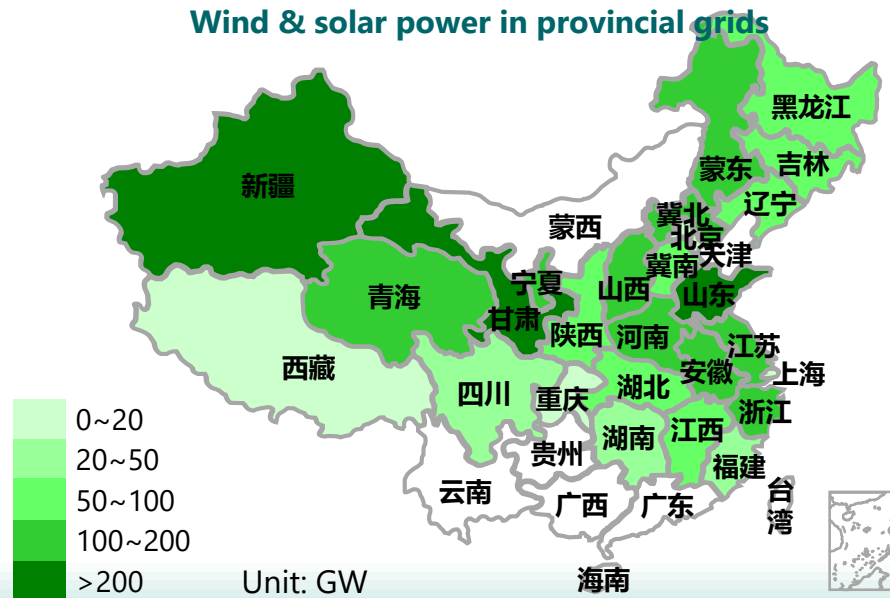


In 2011~2017, the average annual growth of hydro, wind and solar power generating capacity were 6%, 24% and 93%, respectively. By July 2018, SGCC has 504 GW of renewable power generation installed in its service area (225 GW hydro, 137 GW wind, 142 GW solar with 39 GW distributed PV).

Renewable power generation in SGCC



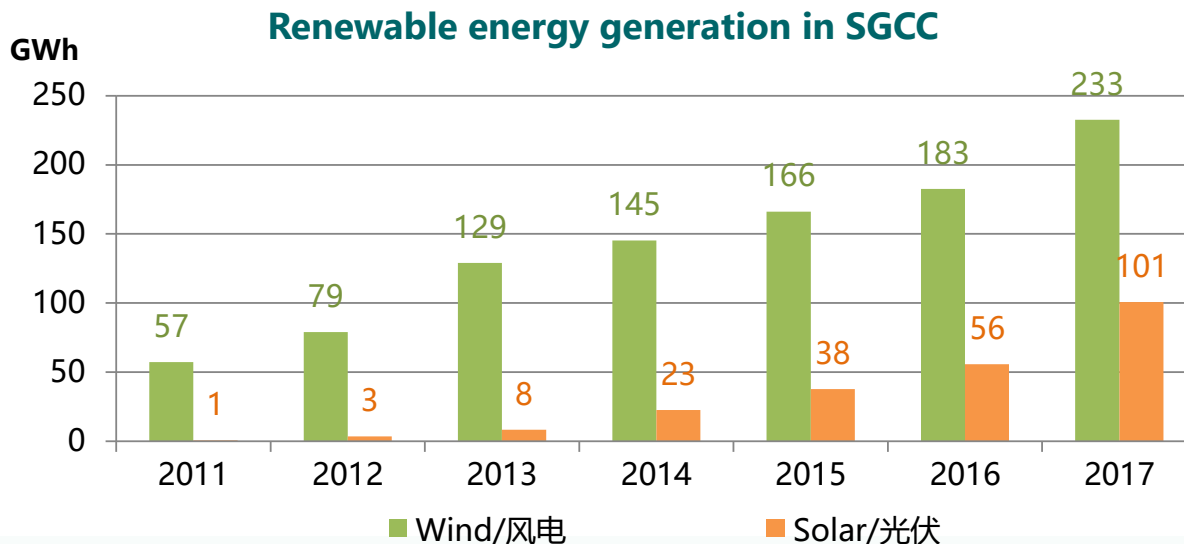
Wind & solar power in provincial grids



Wind & Solar Energy Consumption



In 2011~2017, the average annual growth of wind and solar energy consumption were 26% and 134%, respectively. In 2018, wind and solar energy accounted for 8.4% of the total electricity generation in SGCC by August; the growth rate of wind and solar energy consumption (38.4%) was much higher than that of total electricity consumption.



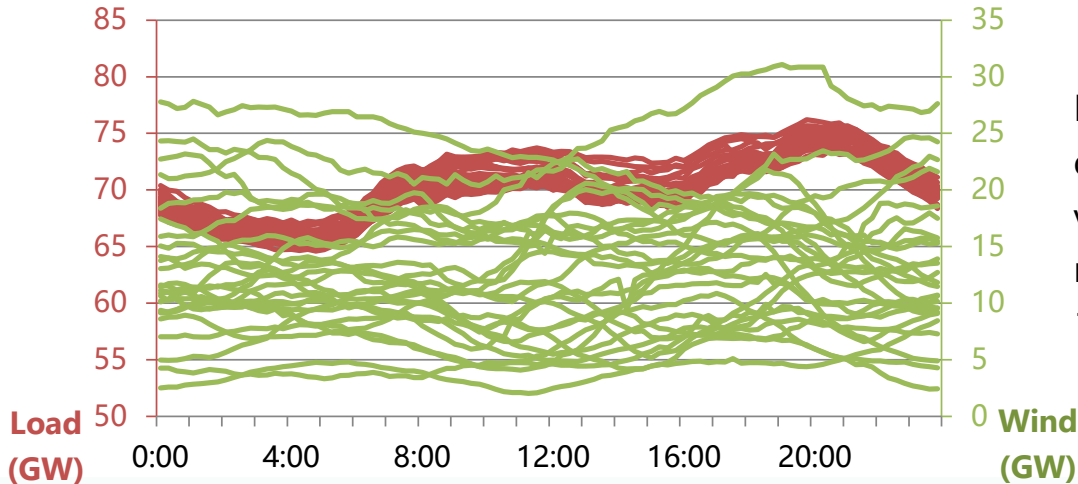
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Difficulties on Load Following



The volatility of wind power output results in difficulties on load following. In 2017, the total wind power output in SGCC varied from 63 to 7.9 GW, and the maximum intraday variation reached 32 GW. China heavily relies on coal power with limited regulation capability, while flexible power sources contributes a very small portion. The grid regulation capability further reduces during heating period.

Load and wind power in Northwest China, March 2018

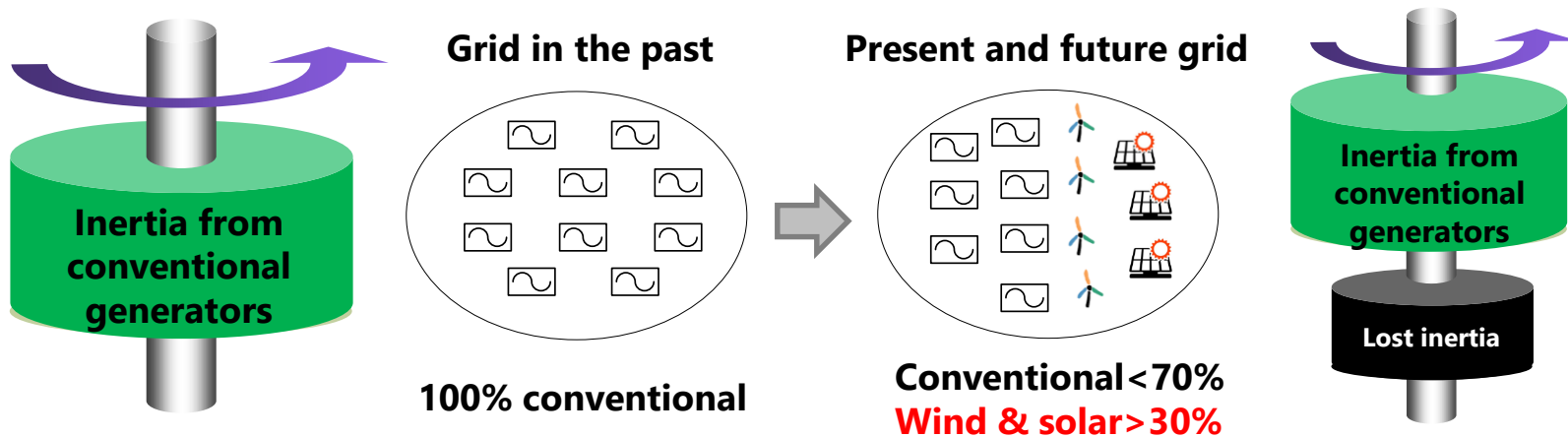


In March 2018, the wind power output in Northwest China grid varied from 2 to 31 GW, and the maximum intraday variation reached 17.72 GW.

Challenges from Power Electronics



Wind and solar power generation is integrated into the system via power electronic components, which lacks active/reactive power regulation abilities. As conventional generators are replaced by wind and solar power, the system presents **weaker inertia, damping and robustness** to grid disturbances. This is a large challenge to the security and stability of the system.



The evolution of power system in China

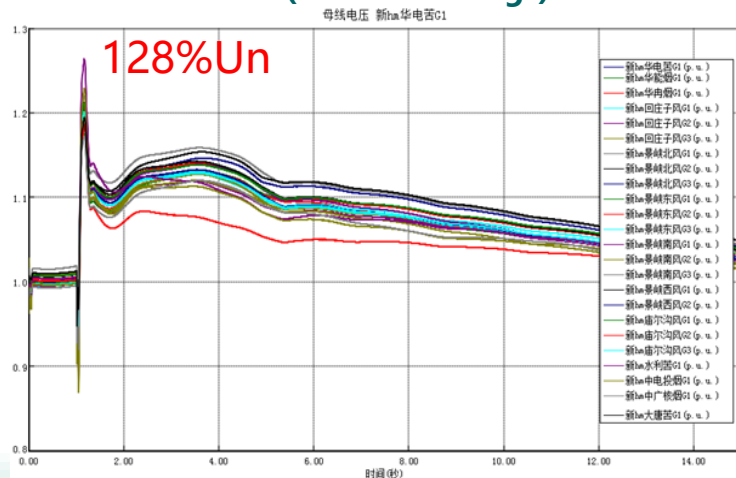
Intolerance to Grid Disturbances



Wind and solar power generation lacks tolerance to grid disturbances such as high frequency and high/low voltage. It may be off the grid after a grid fault and worsen the situation.

- ◆ In January 2014, the transient overvoltage (128%Un) caused by a Tianshan-Zhongzhou UHVDC fault resulted in the loss of 25 wind turbines by overvoltage protection in Qiaowan wind farm which is 400km away from Tianshan station.

Overvoltage caused by Tianshan-Zhongzhou UHVDC fault (PMU recordings)



Comparison of tolerance levels of wind turbines and coal-fired generators

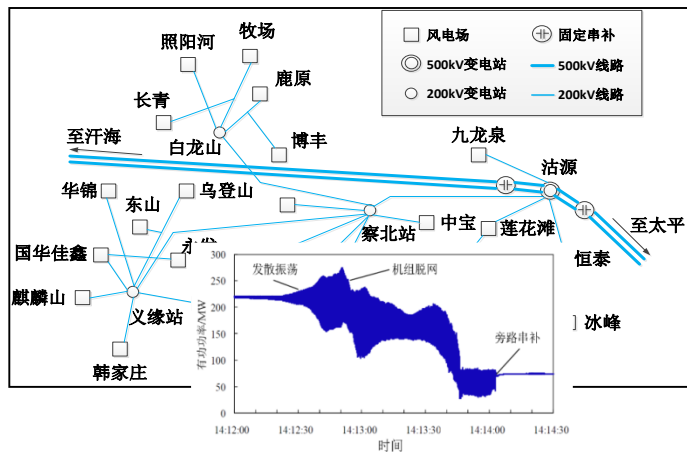
	Wind	Coal-fired
Overvoltage	1.1 p.u.	1.3 p.u.
Overfrequency	50.2Hz	51.5Hz
Primary frequency response	None	6%
Power factor	0.95 leading ~0.95 lagging	0.95 leading ~0.85 lagging

Grid Oscillation Problems

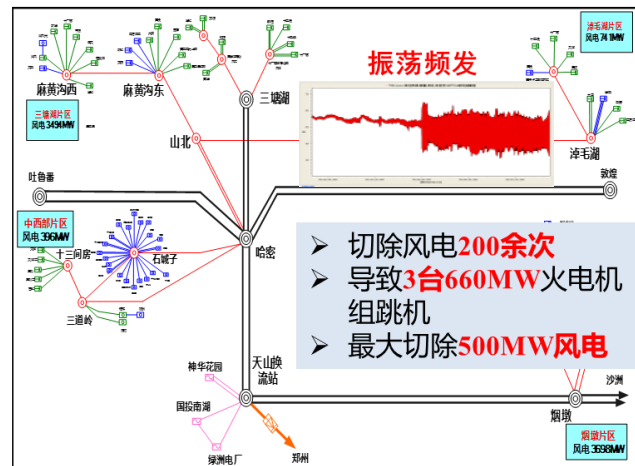


Multi-form **sub/super-synchronous oscillations (SSOs)** are likely to occur in a weak grid with high wind power penetration.

- ◆ Since 2015, more than 100 SSOs have happened near Tianshan-Zhongzhou UHVDC converter stations and wind farms in Hami, Xinjiang.



Wind power oscillations in Guyuan, Hebei



SSOs triggered by wind power in Hami, Xinjiang

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Analyzing Grid Characteristics



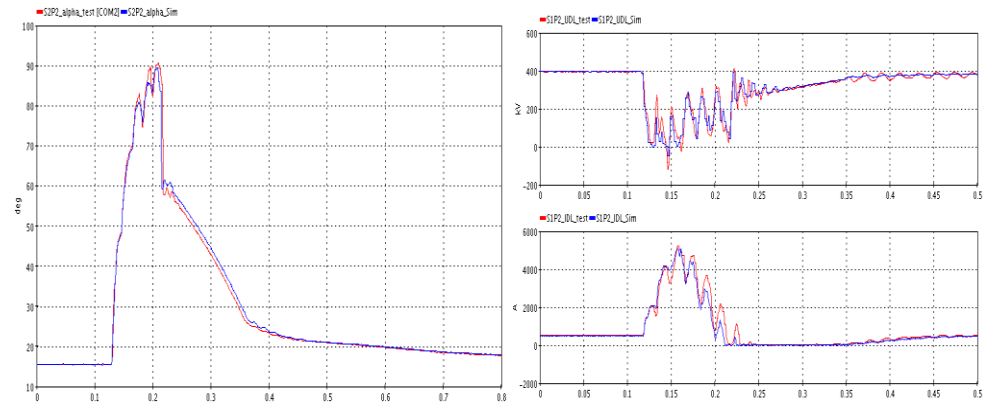
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SGCC performs researches and innovations on basic theory, grid control and simulations, which improves the recognition of grid characteristics.

- ◆ Construct the world's largest **hybrid analog/digital real-time power system simulation platform** and the first 900-Tflops **supercomputing platform** designated for power system simulation.
- ◆ Conduct **hybrid electro-mechanical/electro-magnetic transient simulations** to accommodate the trend of power-electronization of power systems.



Supercomputer center

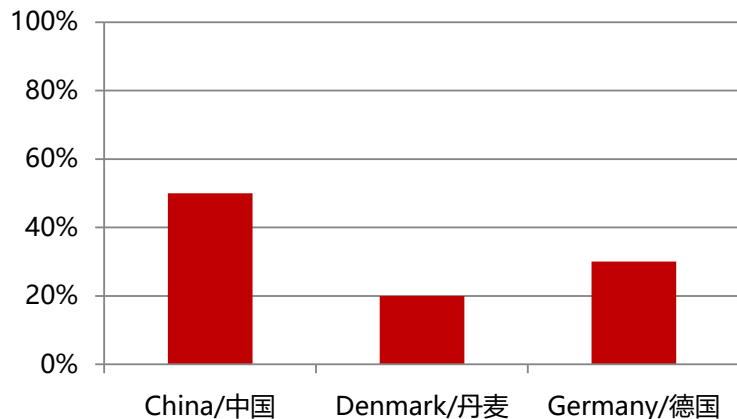


Verification of UHV DC simulation models

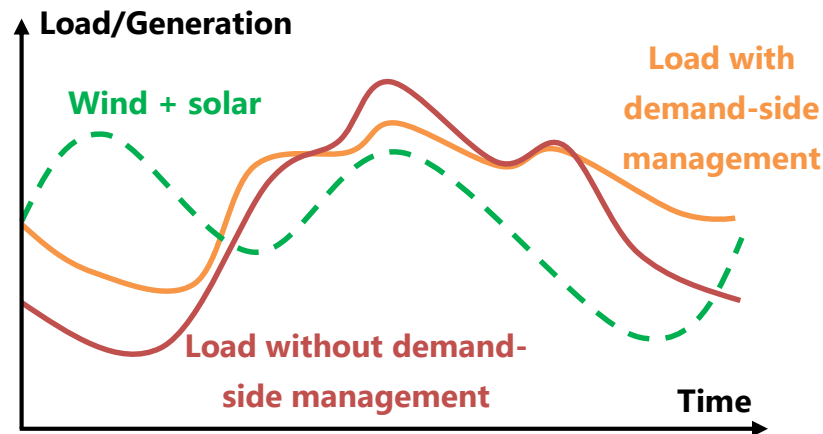
Improving Regulation Capability



- ◆ Support the upgrade of **coal-fired generators** to allow lower minimum load levels for wider ranges of power output adjustments.
- ◆ Promote **grid-scale energy storage** and expedite the construction of pumped-hydro plants. Over 24 GW of pumped hydro is expected to be in service by 2020.
- ◆ Establish power balancing mechanism with **distributed energy storage** and **demand response**, and make room for renewable energy through markets of generation rights and ancillary services.



Minimum load level of coal-fired generators

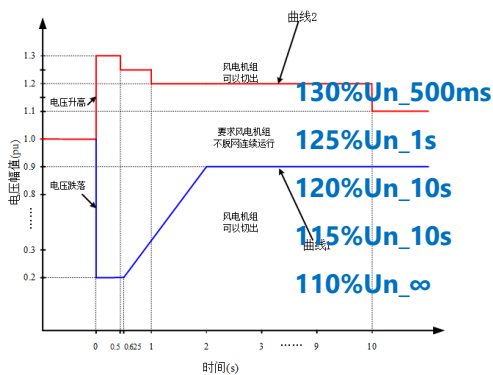


Power balance affected by demand-side management

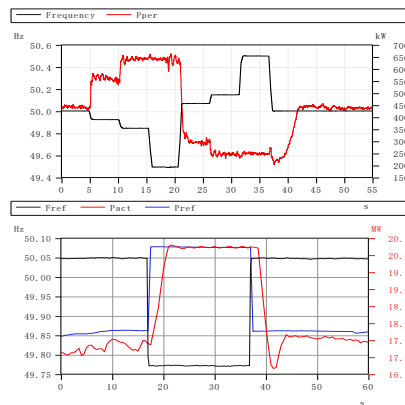
Promoting Grid-friendly Wind & Solar Power



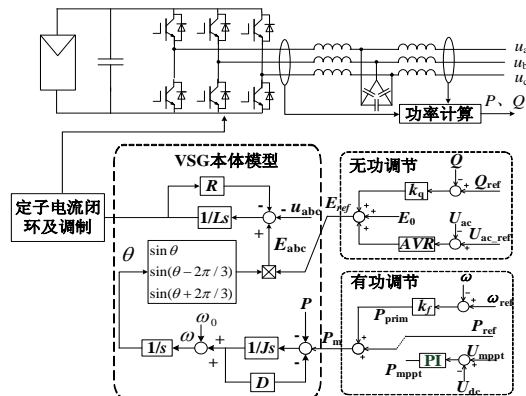
- ◆ Revise the grid code compliance to include **high/low voltage ride-through (LVRT/HVRT)** requirements for wind turbines, and construct testbeds to support the upgrade of wind turbines for LVRT/HVRT capabilities.
- ◆ Conduct researches on **primary frequency response (PFR)** capability of wind turbines and wind farms, and carry out experiments in Northwest China grid.
- ◆ Promote **virtual synchronous generator (VSG)** control of wind turbines and PV units to enable grid-friendly capabilities including inertia, damping, PFR and reactive voltage regulation.



Revised requirements on LVRT/HVRT of wind turbines



PFR test on wind turbines and wind farms

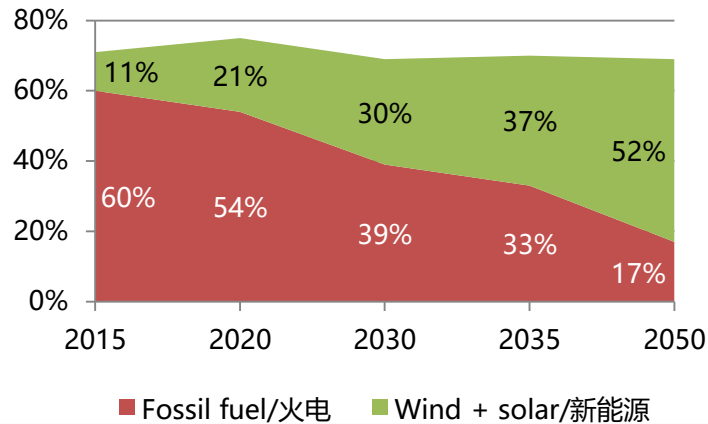


VSG control of PV inverters

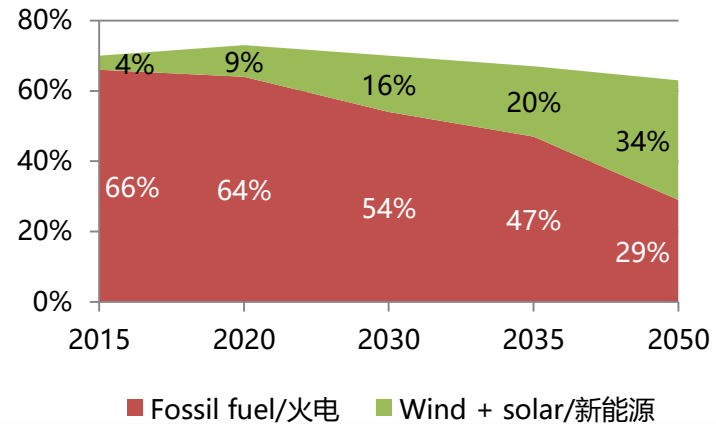
Conclusion and Outlook

By 2030, wind and solar power in SGCC is expected to make up 30% of generating capacity and 16% of electricity generation; the proportion will further rise to 50% and 30% by 2050. SGCC will dedicate to a next generation power system with better connectivity, intelligence, flexibility and safety, and actively promote the development of renewable power to support China's transformation towards clean and low carbon economy.

Generating capacity 2015~2050



Electricity generation 2015~2050





Thank you for attention!