Views on enhancing the consumption capacity of renewable energy resources

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1 Large - scale wind power generation practice in China

2 multiple-energy cooperation extends the ways of renewable energy consumption

—Scale development and long-distance transmission by high voltage level of wind power is the main feature in China.

2016, wind generation capacity is up to totally 132GW.

In China, by 2020, there will be 8 wind generation bases to be built, such as Xinjiang, Gansu, Inner Mongolia, hebei, jilin, jiangsu and shandong, EACH CAPACITY MORE THAN 10 GW.

Research Background

The future electricity energy flow in whole

- The primary energy resources are located far away from load centres.
- Clean energy utilization, rapid growth of power supply in load centres, energy conservation and reduction of pollutant emissions.
- UHVAC and UHVDC transmission technology applicable to long-distance and large-capacity energy transmission.

Research Background

- 4 synchronous grids
- 159 GW
- 6 UHVAC and 5 UHVDC

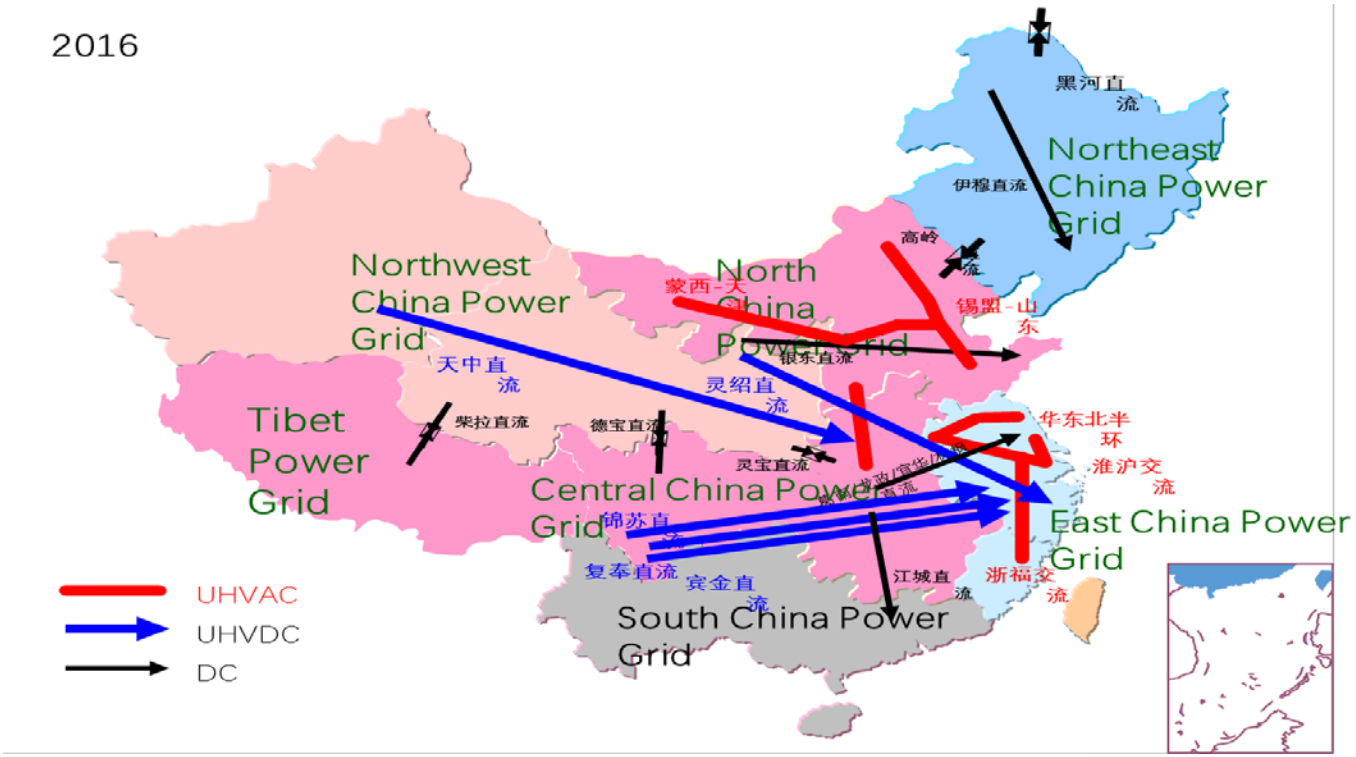


Diagram of UHV interconnection between regions

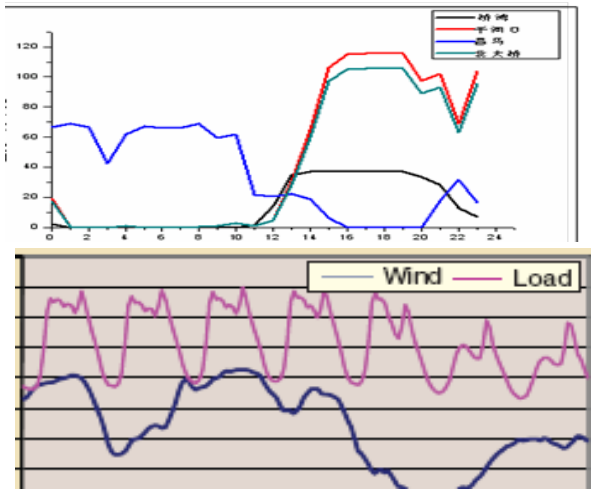
Transmission projects	Finish date
Changzhi-Nanyang-Jingmen	2009.01
Fufeng	2010.07
Jinsu	2012.12
Huainan-Shanghai	2013.09
Tianzhong	2014.01
Binjin	2014.06
Zhejiang-Fujian	2014.12
Lingshao	2016
East China UHV North Semi-ring	2016
Ximeng-Shandong	2016
Mengxi-Tianjin	2016

random, intermittent,
fluctuant,
anti-peak shaving
time-space volatility

make it hard to control

To ensure the grid safety, dispatchers always limit wind farm's output

The wind farm's capacity can not be fully utilized

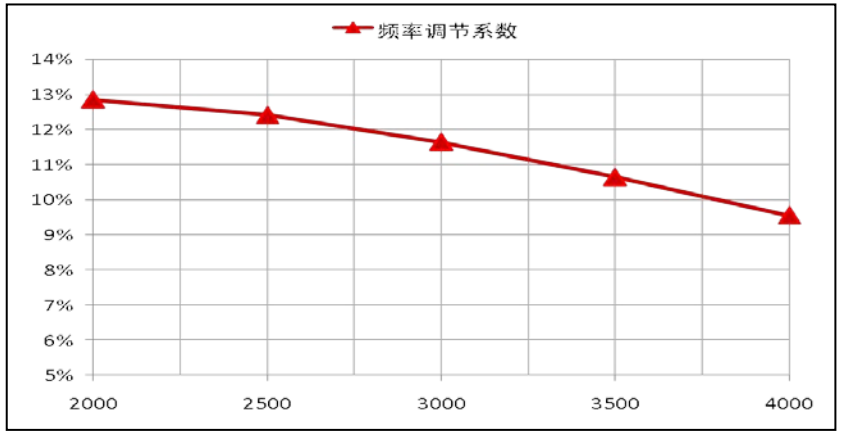


Sudden power output changes due to wind speed variation ;
Tripping off due to sudden low or high voltage events;
High Var consumption of induction generation;
Unable to regulate voltage within required limits;

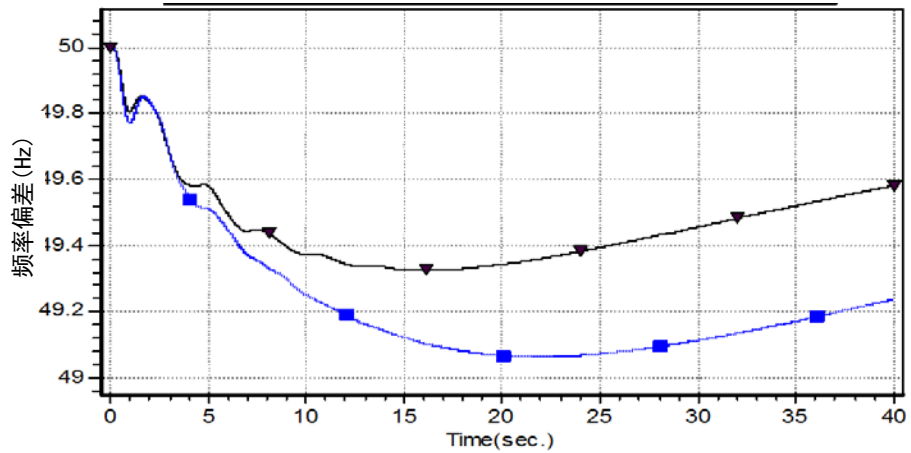
Power grid structure as well as operating characteristics have deeply been changed

- The power grid presents integration features and **the risk of grid operation increases.**
- Long-distance and large-capacity power transmission. Fault disturbance impact rising.
- **A major change is happening in power source structure. The control capability of the grid declined seriously.**
- **Power electronic devices reveal new problems in power systems. Stable form is more complex.**

A major change is happening in power source structure



East China frequency multiplier changes with fed DC capacity(Load level 180 million)

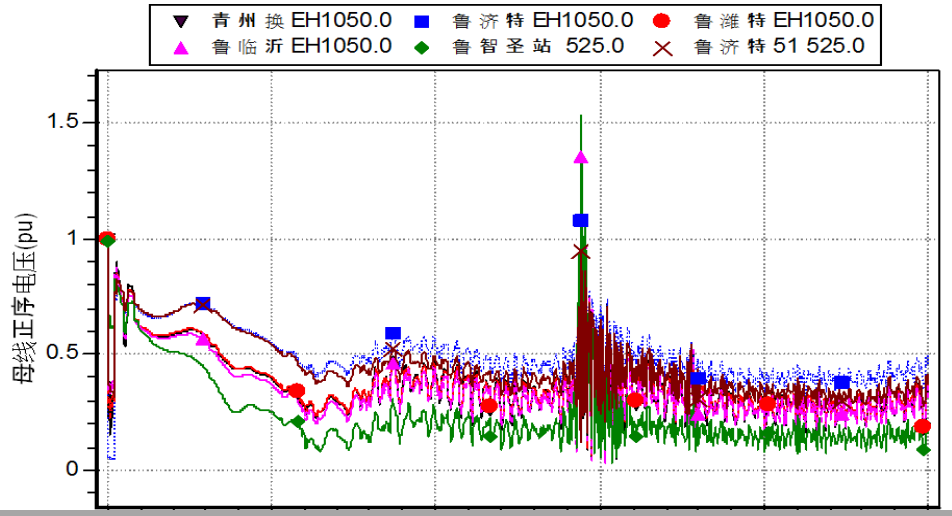


Frequency curve when the presence or absence of wind power（68 million load, 3.5 million loss）

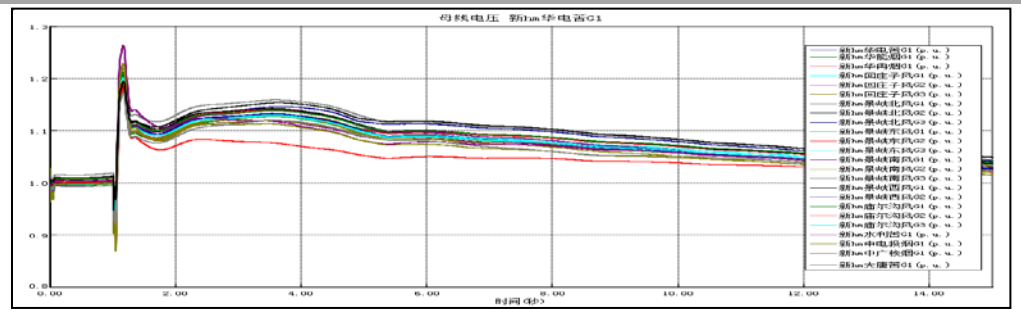
In terms of frequency

- Conventional units are replaced by large number of new energy unit
- Grid inertia continues to decrease
- Frequency adjustment ability decline

A major change is happening in power source structure



The voltage of Shandong grid collapsed caused by multi-DC feed in



The transient overvoltage of the sending end is about 1.2 times the rated voltage during the single commutation failure

In terms of voltage

Dynamic reactive power reserve fall sharply, the ability to regulate the voltage reduces, the risk of grid voltage collapse increases.

	Wind power	Thermal power
Upper limit for voltage-resistant capacity	1.1	1.3

Electronical grid compare with traditional AC grid

	Traditional AC grid	Electronical grid
Stability problem types	Power frequency related problems （Electromechanical transient）	Power frequency, sub-synchronous frequency and super-synchronous frequency related problems （Electromagnetic transient）
Fault impact	Mainly Local fault	Extent to other area
	Low probability of systemic frequency problem and voltage problem	High probability of systemic frequency problem and voltage problem
	Low risk of cascading failure	High risk of cascading failure

Power electronic devices reveal new problems in power systems

The increasing significance of power electronization has brought 2 problems:

- On one hand, the standards for the grid-related performance of various electronic devices are quite low.

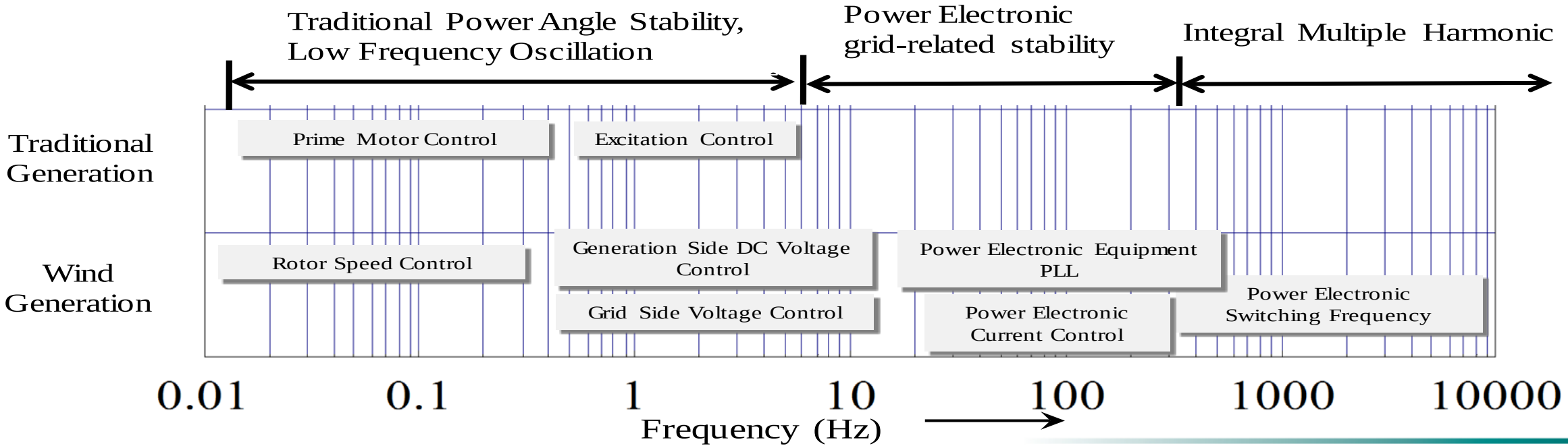
Frequency and voltage capacity of Power Electronics

	Upper limit for voltage-resistant capacity (p.u.)	Upper limit for frequency-resistant capacity(Hz)	Lower limit for frequency-resistant capacity(Hz)
Thermal	1.3	46.5	51.5
Wind	1.1	48.0	50.2
Solar Farm	1.1	48.0	50.5
HVDC	1.3	49.0	51.0
SVC	1.1	48.0	50.2

Power electronic devices reveal new problems in power systems

The increasing significance of power electronization has brought 2 problems:

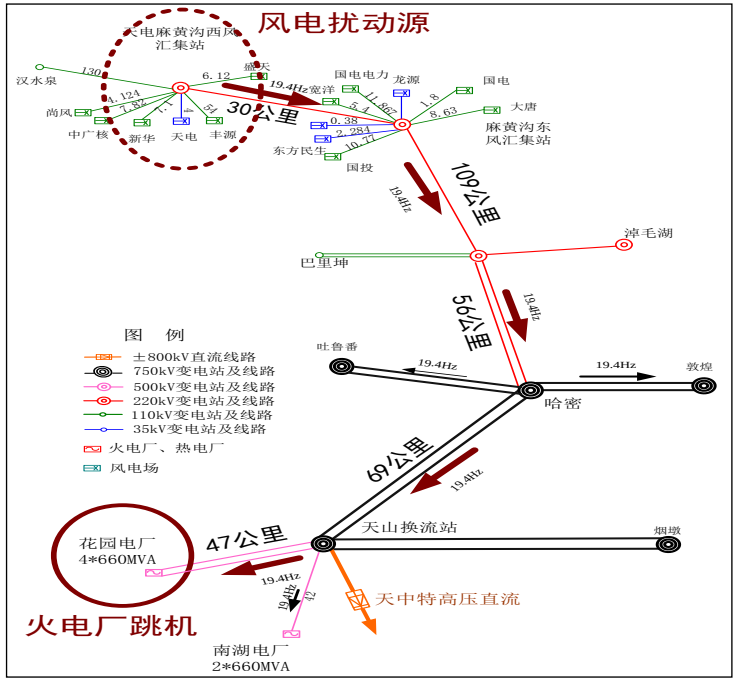
- On the other hand, there are new stability problems in the middle frequency range (5-300Hz) incurred by the grid integration of power electronic devices.

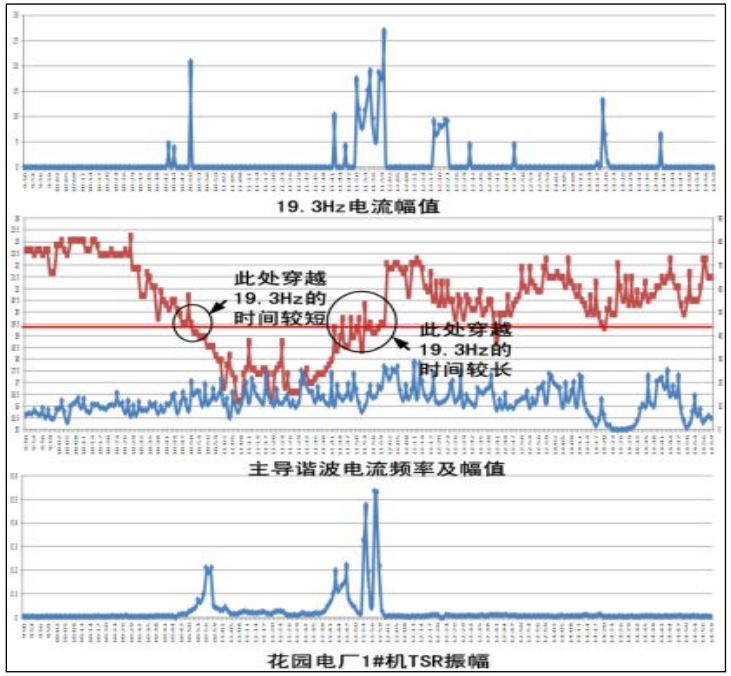


New stable problems caused by wind power

Power electronic devices reveal new problems in power systems

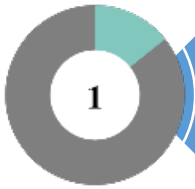
E.g. the Problem of Sub-synchronous Oscillation





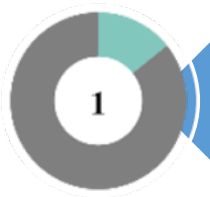
Schematic Diagram of the Sub-synchronous Oscillation in Hami, Xinjiang Province

Main Strategies



Strengthening the main grid structure

Strengthening frequency and voltage control



Improving the renewable energy grid-related performance

Building system protection for the UHVAC/DC power grid

Strengthening the main grid structure

As shown by the operation practices of UHV system, the size of AC power grid must match the capacity of HVDC so that the frequency disturbance caused by the block faults of large capacity DC system can be withstood, and the strength of AC power grid must reach a certain level so that large power disturbance causes by the faults of DC system can be withstood.

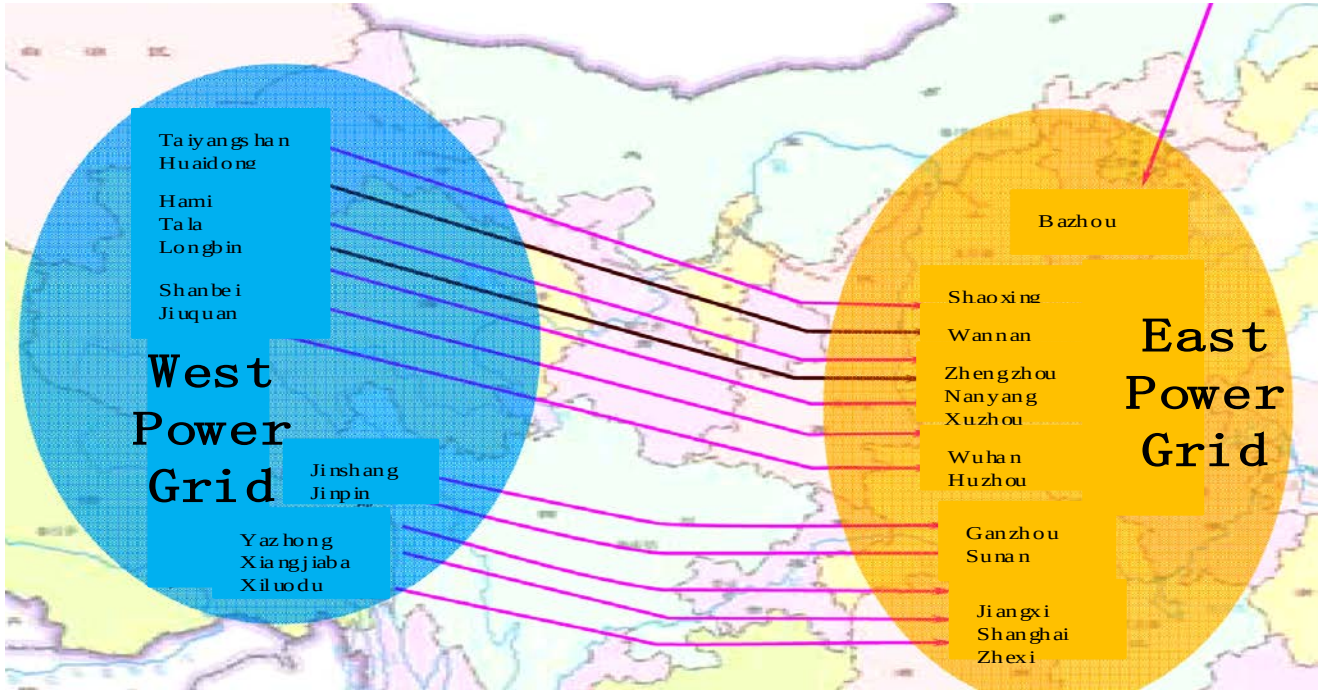


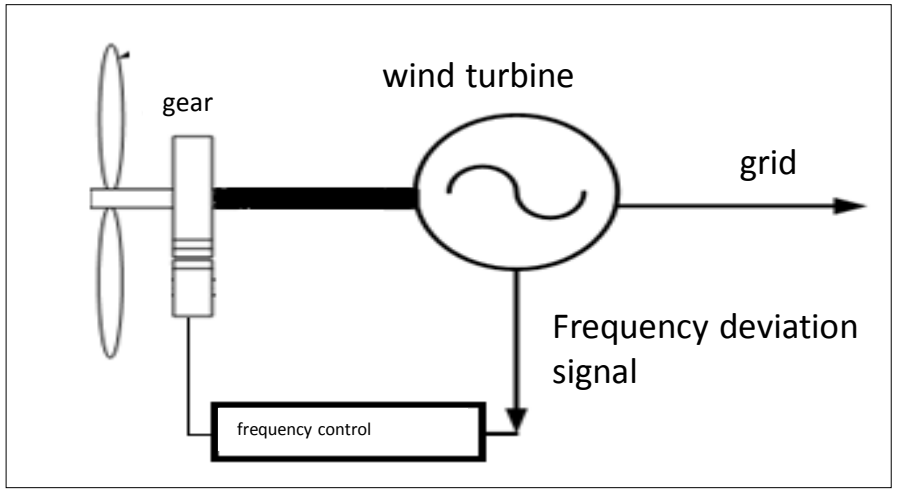
Diagram of the east and west synchronous power grid in China

The key to solve the problem of “strong DC and weak AC” is the construction of strong AC power grid, which can match the capacity and size of DC system.

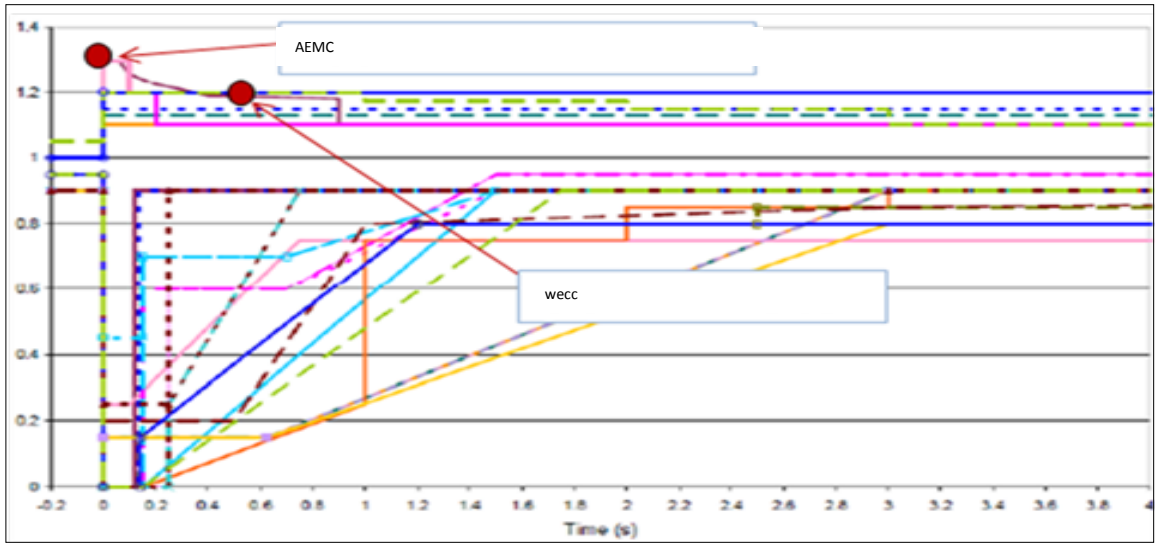
Improving the renewable energy grid-related performance

Improving the renewable energy grid-related standard

The upper limit for voltage-resistant capacity and frequency-resistant capacity of wind and solar far are increased to 1.3 p.u. and 52.5Hz respectively. **The renewable energy is required to be involved in frequency and voltage control to prevent the cascading failure risk induced by large-scale renewable energy disconnection from the grid**.



System operation and control strategy should be adjusted so that the wind units are capable to control frequency, and equipping energy storage element could further promote its frequency control ability.



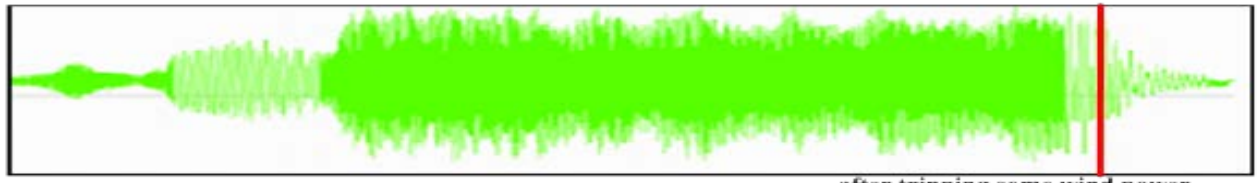
Requirements for high-voltage crossing of several foreign countries

Improving the renewable energy grid-related performance

Systematic exploration and regulation work on sub-synchronous oscillation of renewable energy

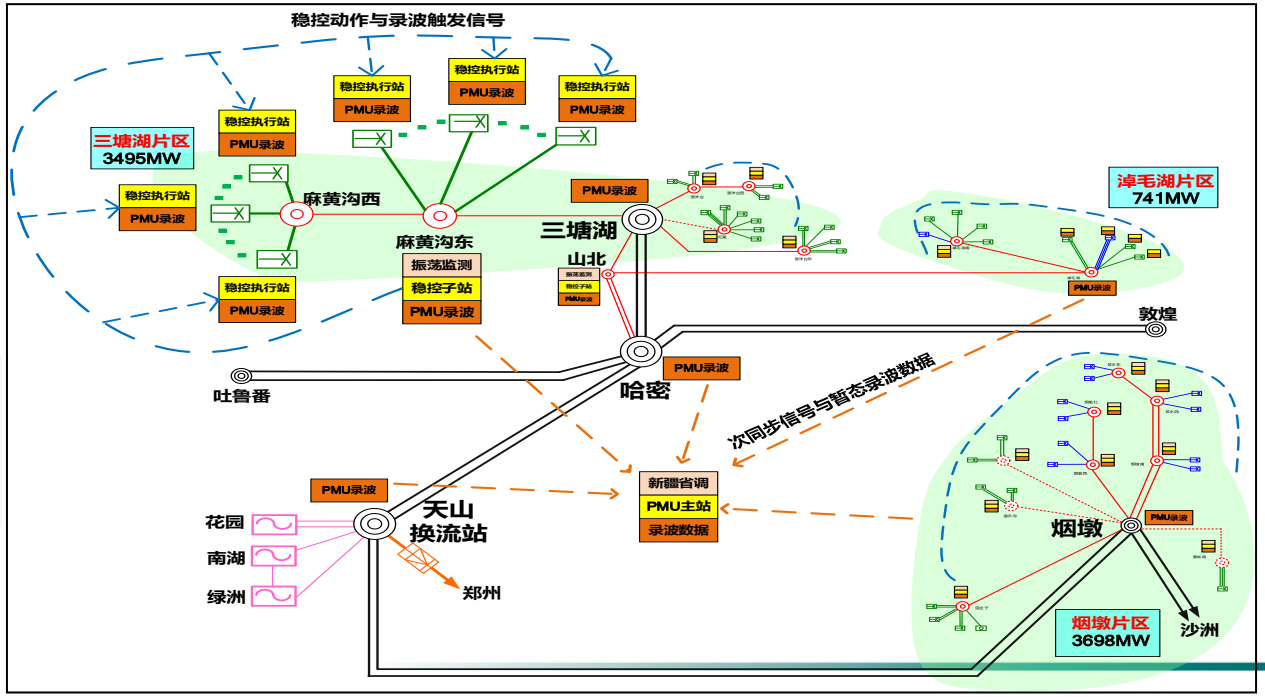
Efforts should be made in implementing security control measures in Hami, where the oscillation problem is quite serious and Standards for renewable energy like wind power units connecting to the grid should be formulated.

Currently, real-time recorded waveform system has been established covering all the key wind farms, monitoring and controlling the sub-synchronous oscillation. The system is of high precision.



after tripping some wind power , subsynchronous oscillation disappears

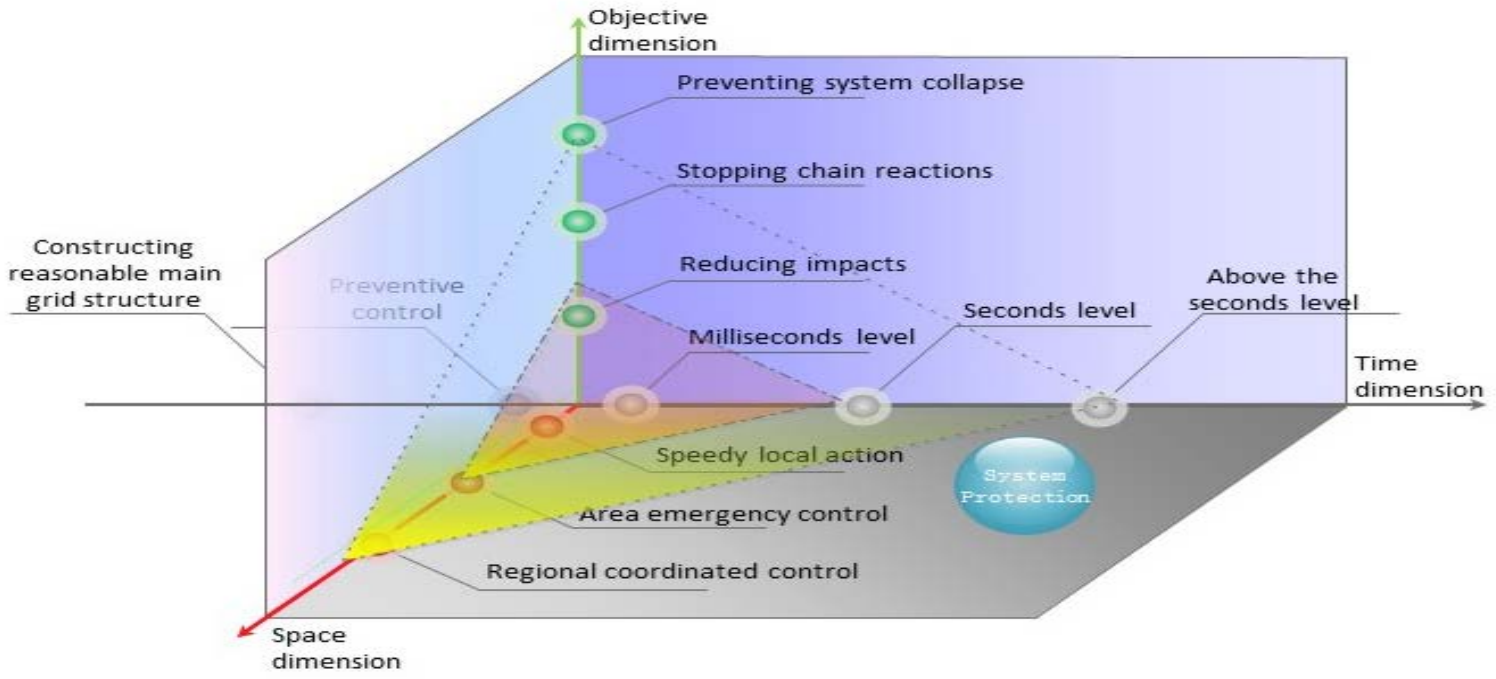
Since the system has been put into operation in the second half of 2015, more than 30 times action (both correct action), effective control of the sub-synchronous harmonic influence.



sub-synchronous oscillation monitoring and controlling system in Hami, Xinjiang

Building system protection for the UHVAC/DC power grid

The concepts of power system operation should be reexamined according to the great changes, and the comprehensive security defense system for large power grid, namely **system protection** (SP), should be reconstructed.



3 dimensions in system protection

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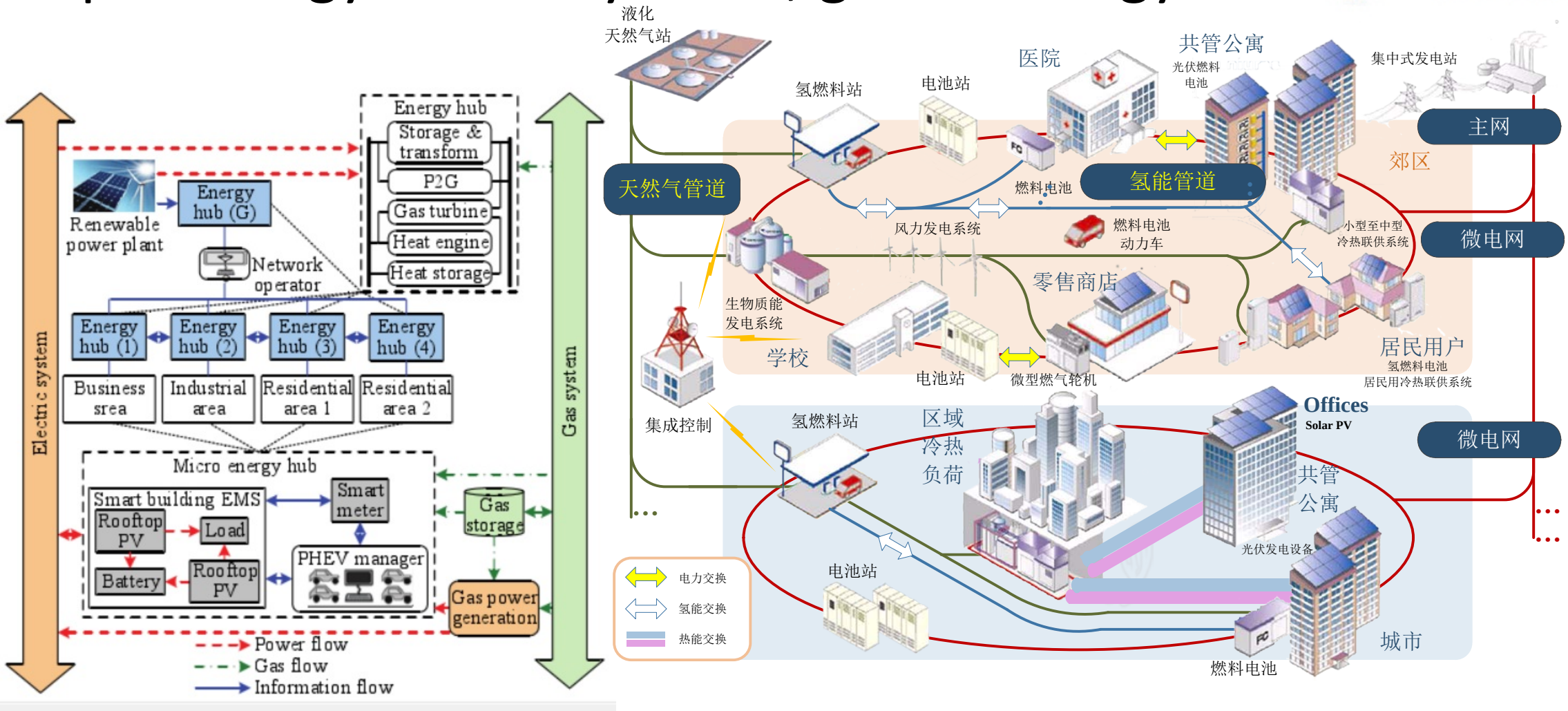
multiple-energy carrier systems, global Energy Interconnection



王一家,董朝阳,徐岩,等.利用电转气技术实现可再生能源的大规模存储与传输[J].中国电机工程学报,2015

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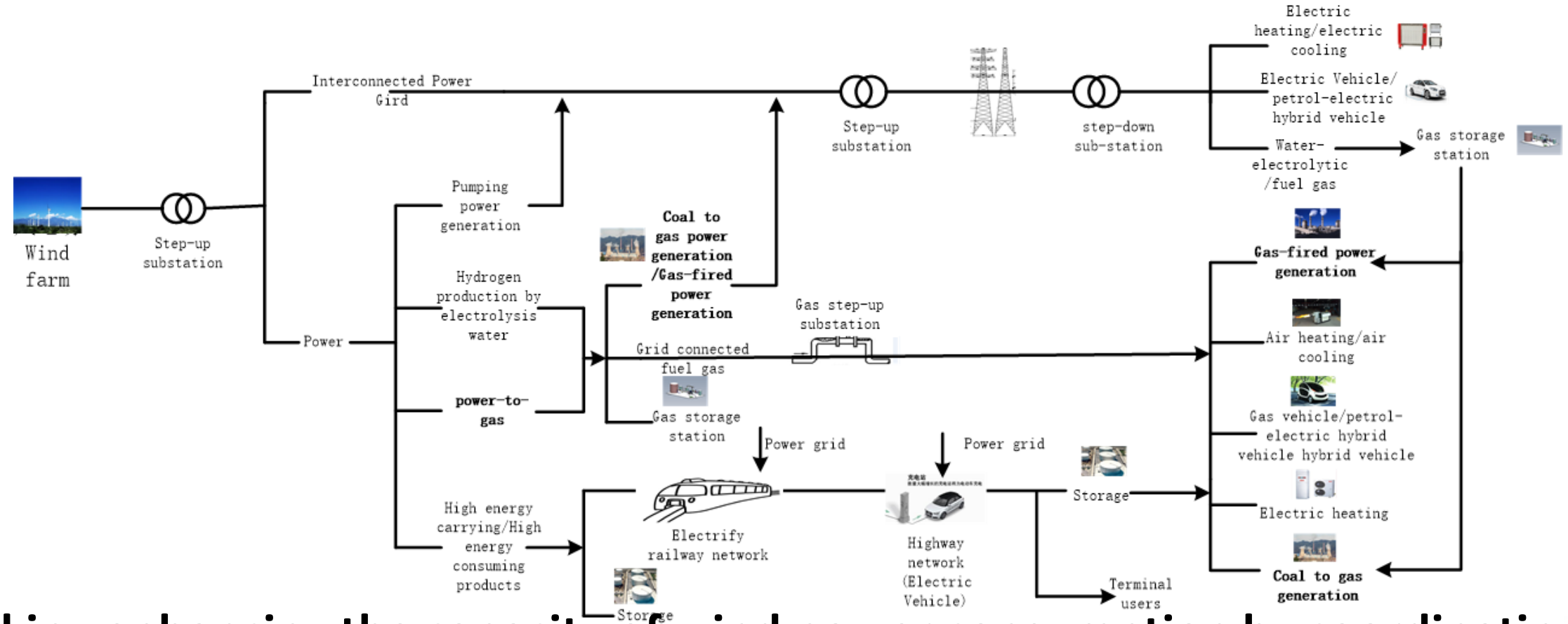
The key to coordinate multiple energy forms is the design of coupling part of different energy forms



Taking enhancing the capacity of wind power consumption by coordinating power network and gas pipe network as an example

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Key1: Energy Storage, Energy form transformation to Improve the renewable energy **dispatch capability**

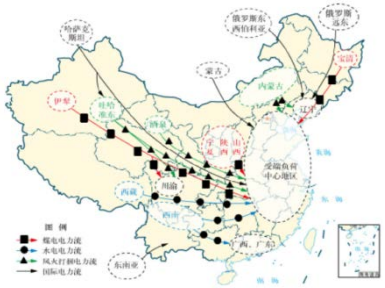
the use of "electricity gas" and other energy forms of conversion, will be converted into storage, easy to transport energy forms, will be from the source to promote renewable energy consumption

Key2:Energy conversion, "Coal to gas" to support the power **grid steady state, dynamic capacity**

Large-scale new energy power generation to replace the conventional synchronous generator, making the grid inertia, short circuit capacity, active frequency and reactive power support capacity dropped significantly.
And through the "coal to gas" makes the existing coal-fired power plants can be re-use. Through the "coal to gas" gas power generation, on the one hand to maintain the grid synchronization inertia and short circuit capacity, its fast FM peaking and reactive power regulation effectively improve the grid acceptance and transmission of renewable energy capacity.

Cooperative power grid, gas pipeline network planning and design and operation regulation and control to enhance the capacity of renewable energy consumption

China energy flow



China Electricity power flow

China Natural Gas Pipeline Network

Railway network map of China

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