Operation &Control Technologies for New Energy Power Generation and Grid Integration

China Electric Power Research Institute

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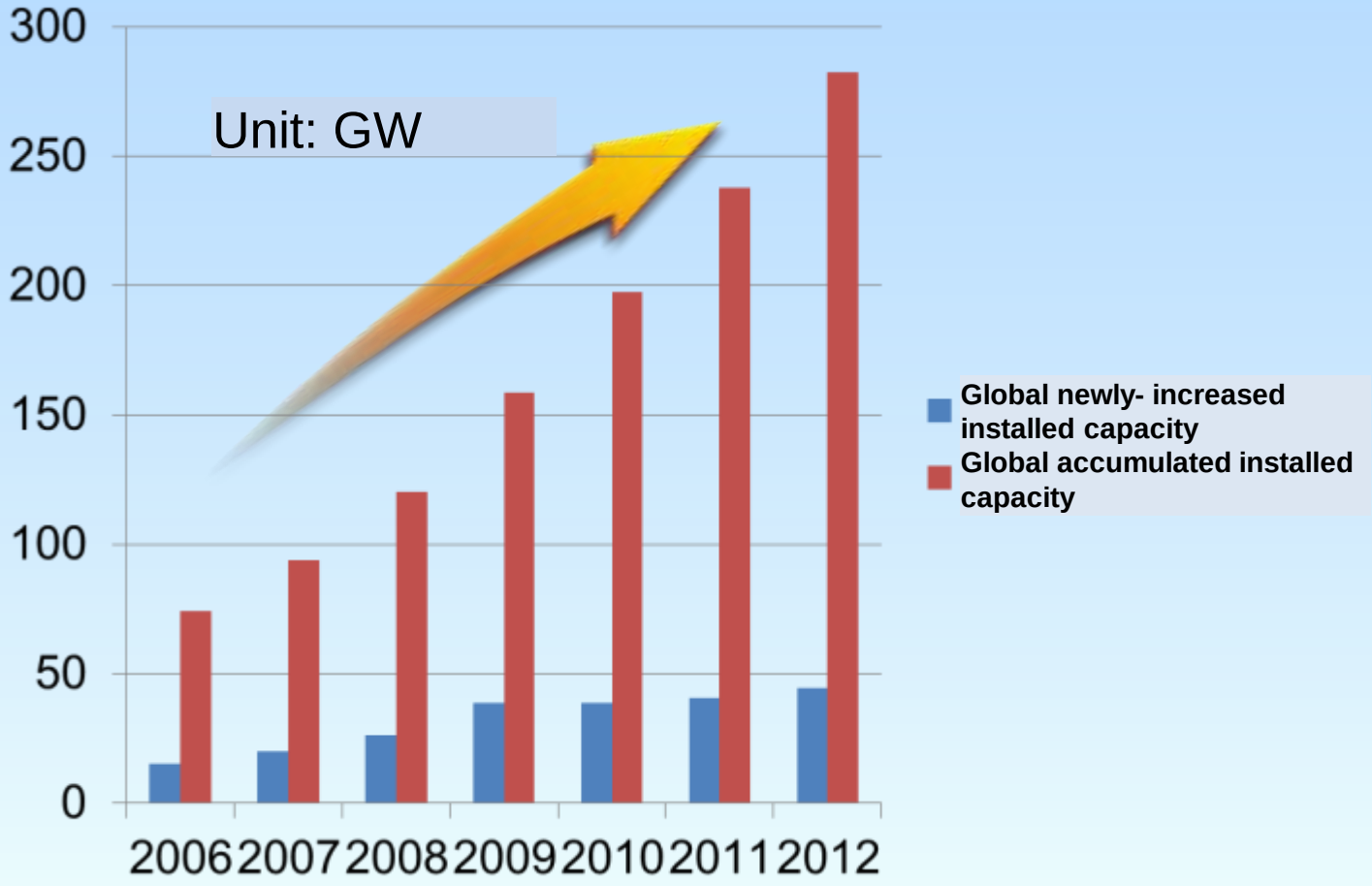
1. Overview of New Energy Power Generation Development

Overview of Wind Power Development

In 2012, newly-increased global installed capacity of wind power was approximately 44GW, with a year-on-year increase of less than 20%, further experiencing a slow-down in growth. It's basically in a development stage with relatively flat growth. By the end of 2012, the total global installed capacity of wind power reached 282GW.



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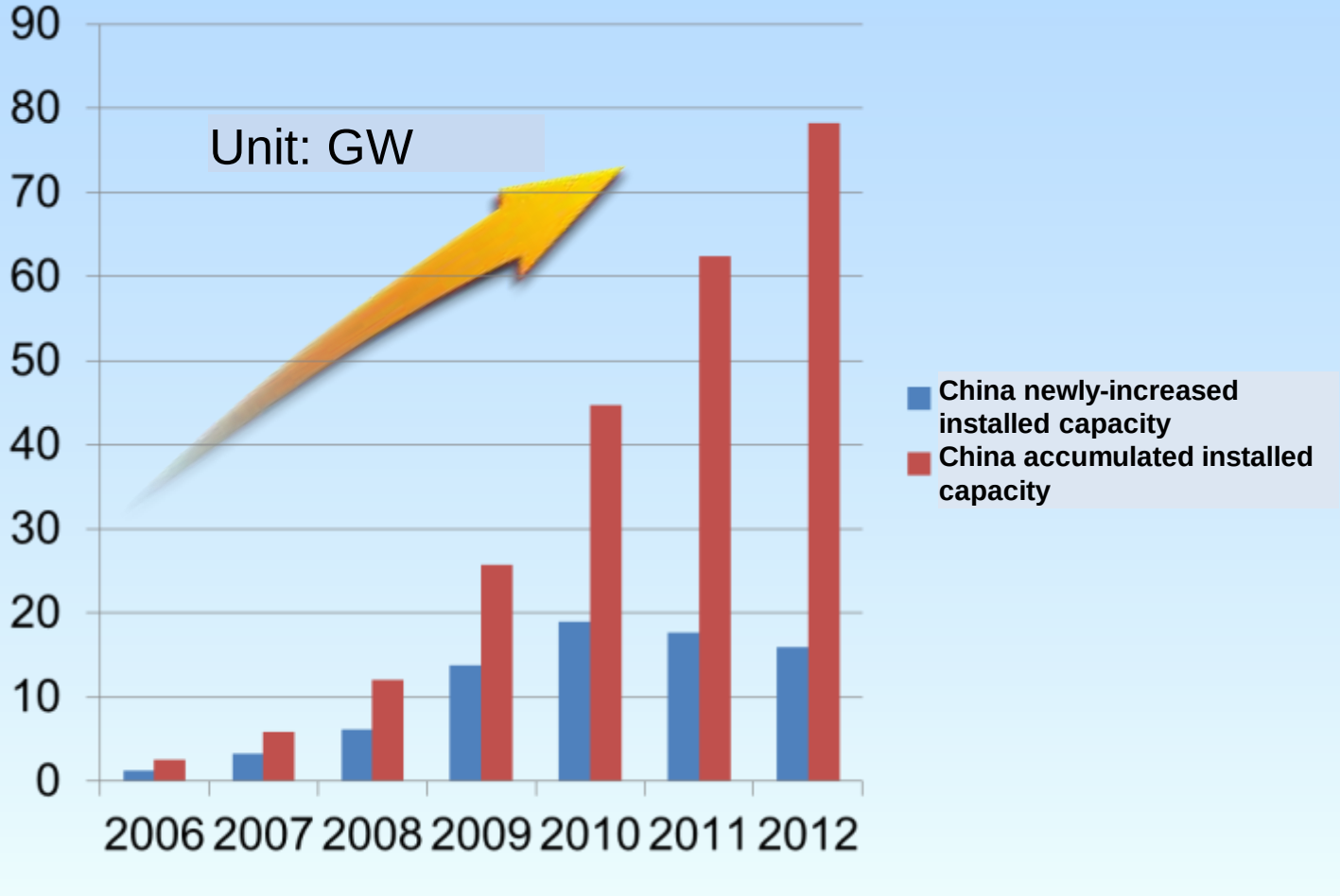
1. Overview of New Energy Power Generation Development

Overview of Wind Power Development

China's national installed capacity of wind power increased from 2540MW to 78.26GW in the past seven years between 2006 and 2012, which is far higher than global average growth.

In 2012, on-grid wind energy across the country amounted to 100.8 billion kWh，accounting for about 2% of national power generation.



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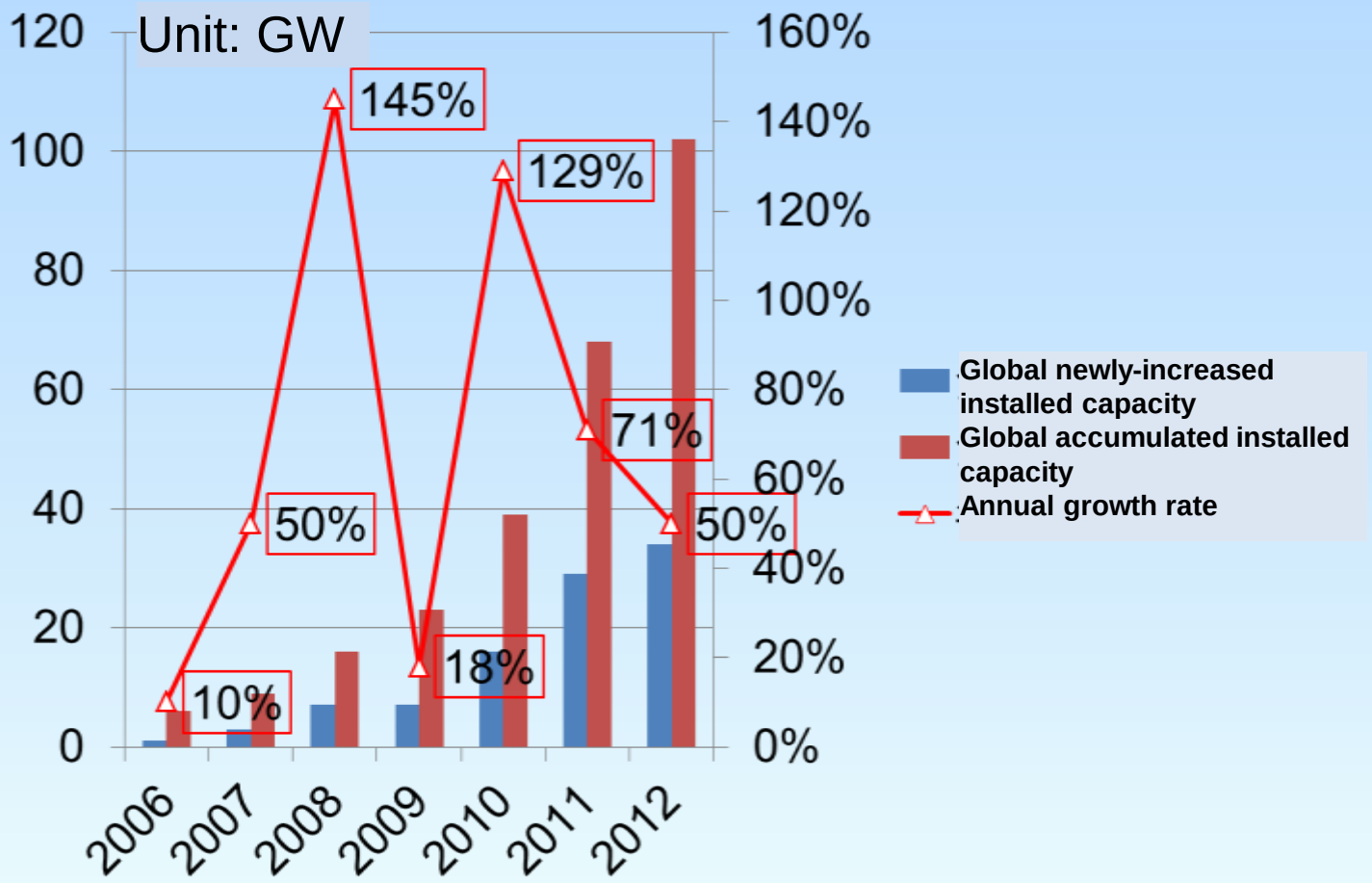
1. Overview of New Energy Power Generation Development

Overview of PV Power Development

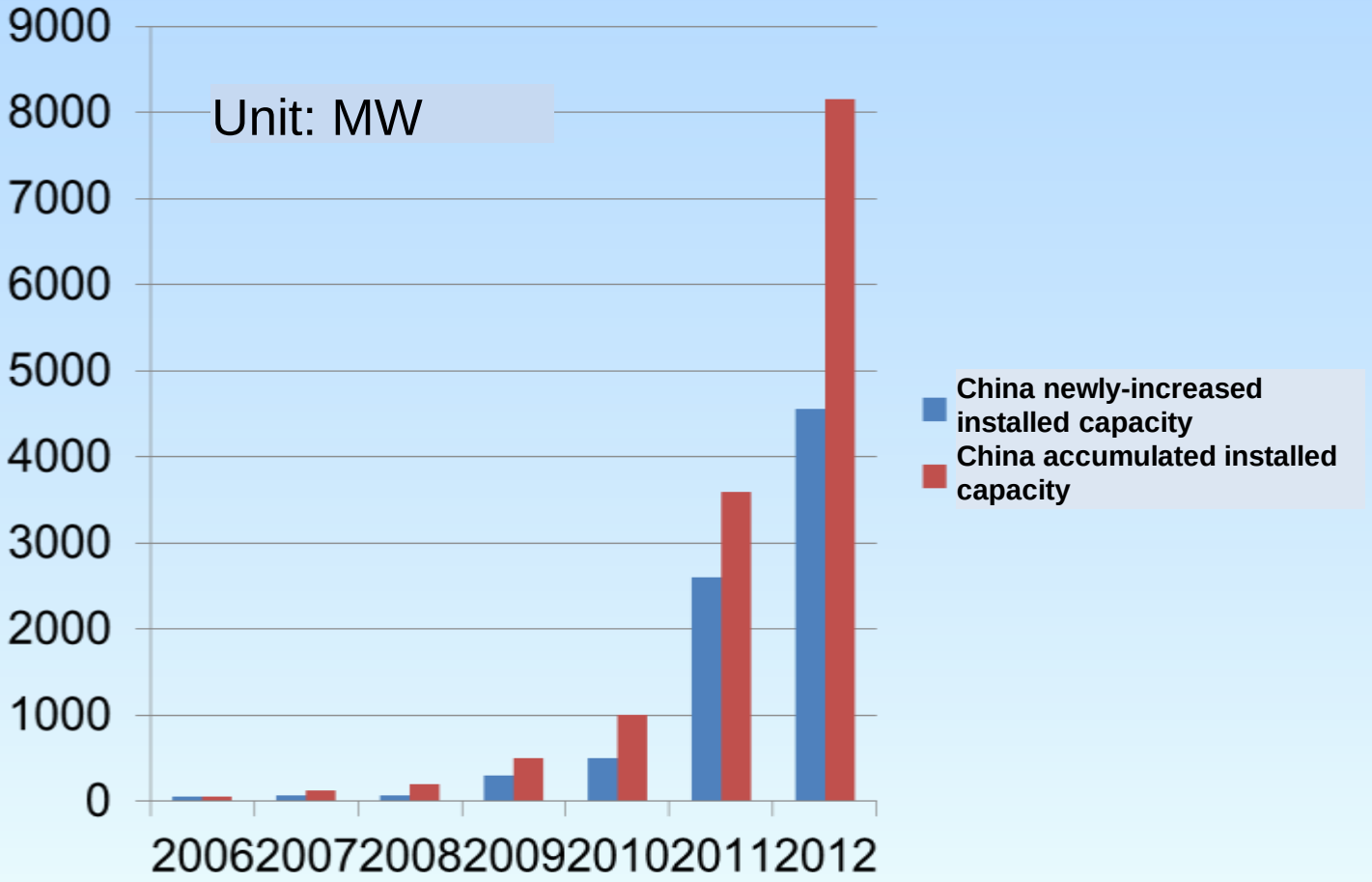
In 2012, global newly-increased PV installed capacity hit a new historical high once again，up to 34GW. Since then, accumulated global PV installed capacity totaled 102GW by the end of 2012.



1. Overview of New Energy Power Generation Development

Overview of PV Power Development

The year 2011 can be said as the first year for PV application in China. Encouraged by a great deal of policy, accumulated projects that are under construction or to be commenced have exceeded 9GW by the end of 2011; the formally completed projects prior to December 30, 2011 have come up to 2.7GW. PV market has been officially launched in China. By the end of 2012, China's accumulated installed capacity has reached 8.16GW.



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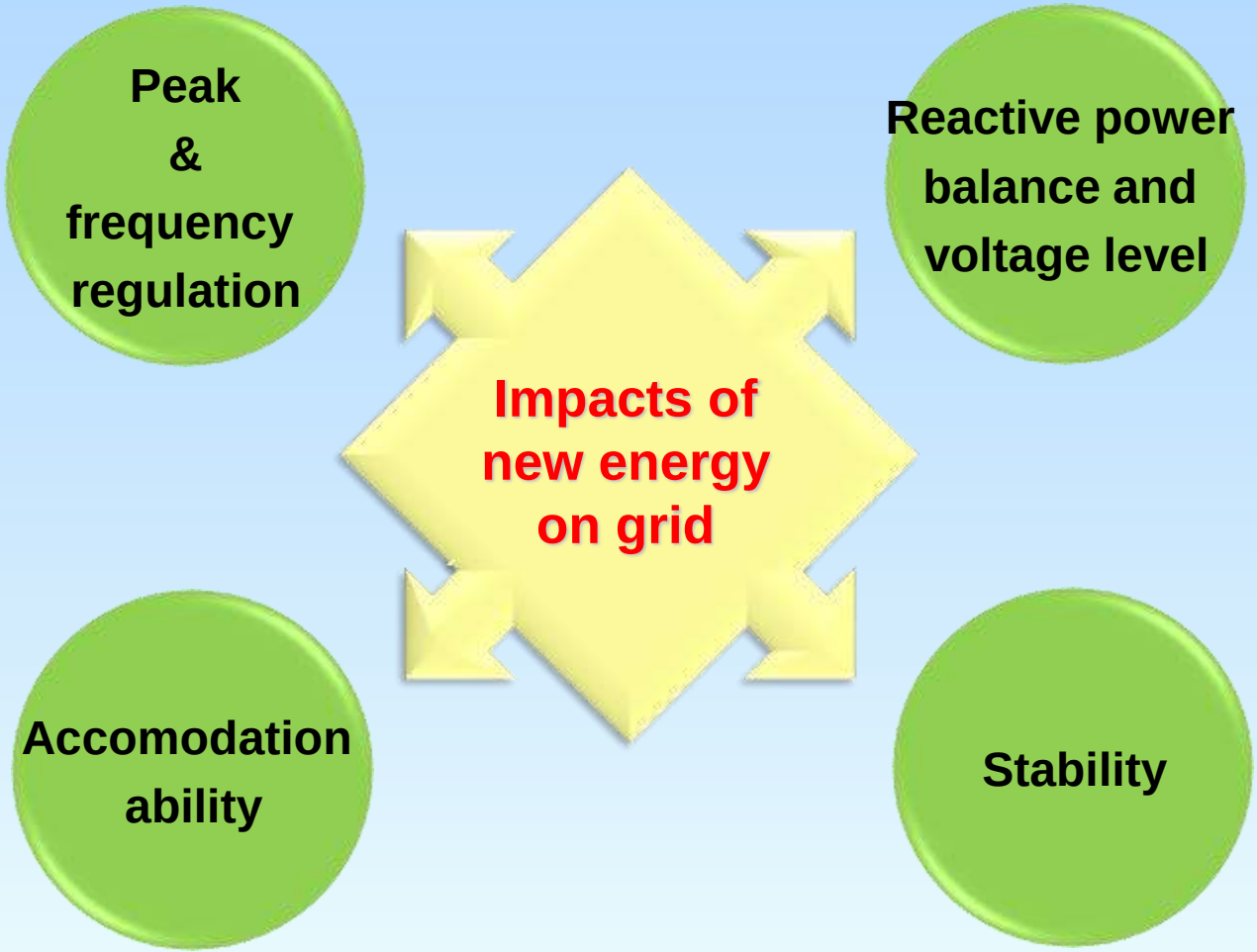
2. Challenges to Grid Operation by New Energy Integration

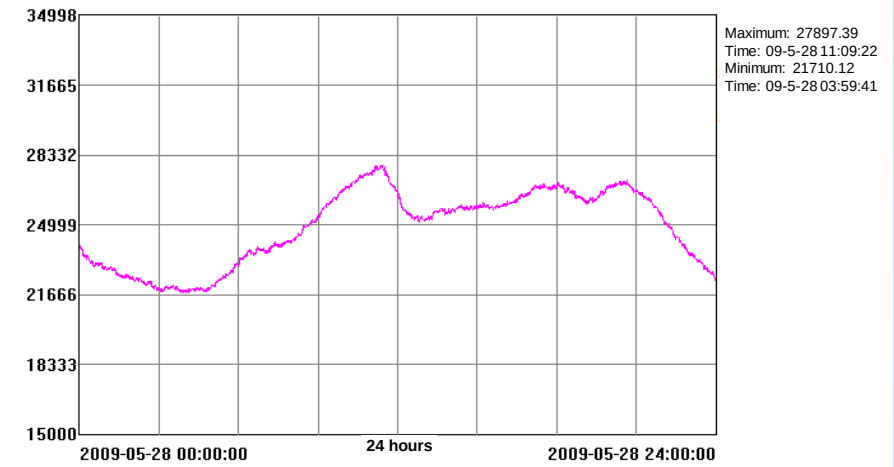


2. Challenges to Grid Operation by New Energy Integration

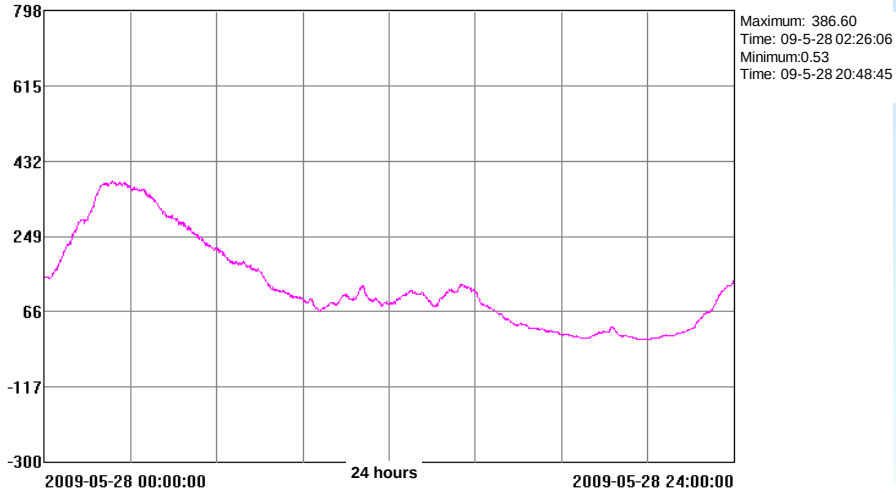
Greater difficulty in system dispatch and peak regulation

- **Distinct anti-regulation properties of wind power output, which renders difficulty in system peak regulation.**

Wind power output and grid load present higher anti-regulation properties.



Load of Beijing-Tianjin-Tangshan Power Grid (MW)



Sum of wind power in Zhangjiakou Wind Power (MW)

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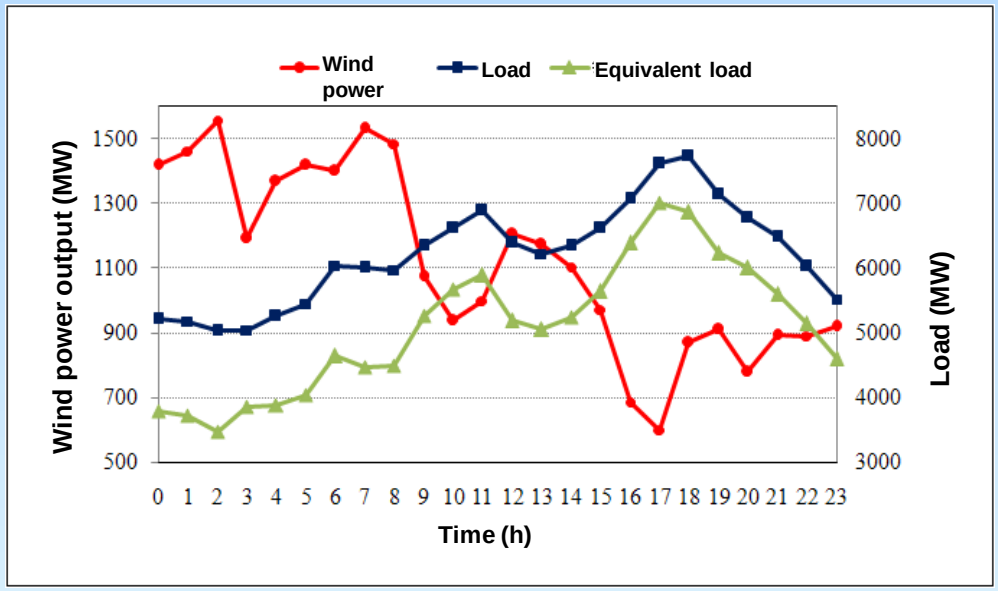
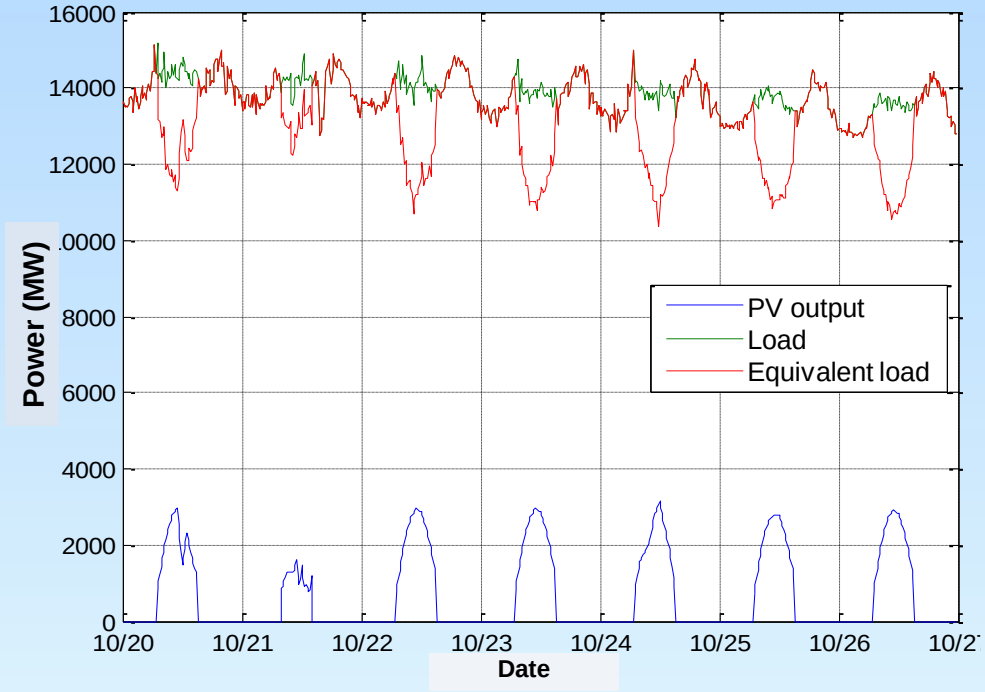
2. Challenges to Grid Operation by New Energy Integration

- **Greater difficulty in system dispatch and peak regulation**

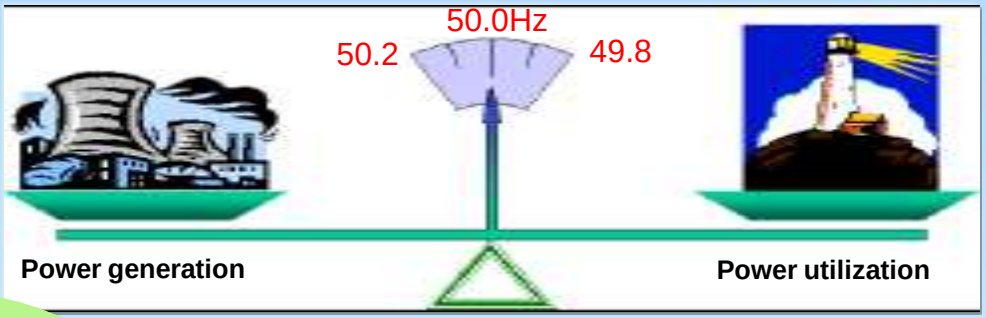




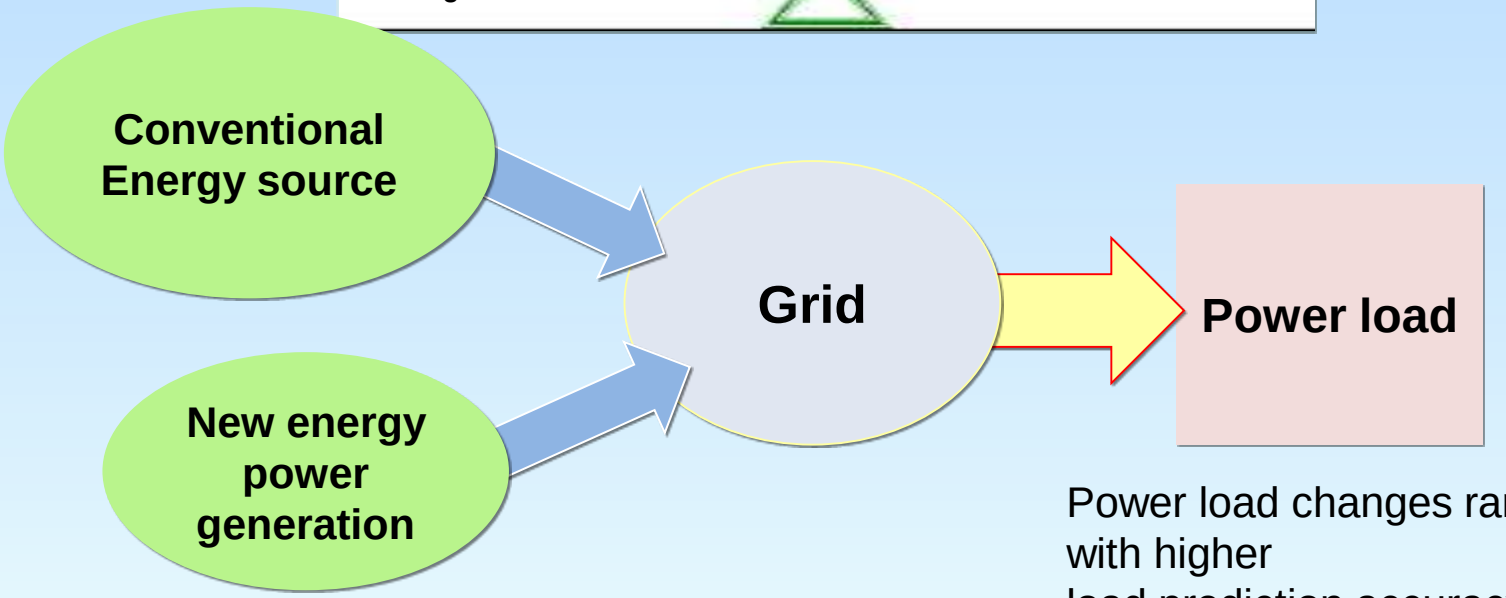
Integration of wind and PV power results in greater fluctuation of equivalent load, and thus bigger difficulty for grid dispatching.

2. Challenges to Grid Operation by New Energy Integration

◆ Greater difficulty in system dispatch and peak regulation



Regulatable power generation output
Controllable prime motor power



Power load changes randomly with higher load prediction accuracy

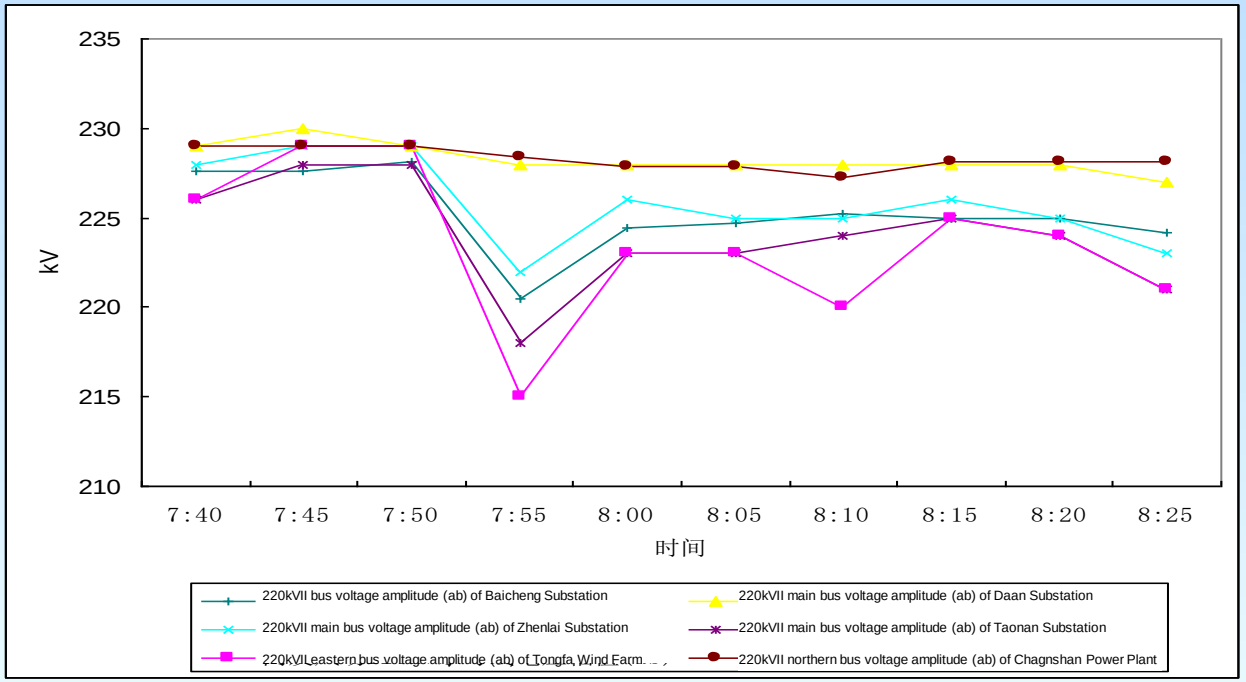
Viable and non-controllable power for new energy power generation**, with low** prediction accuracy

2. Challenges to Grid Operation by New Energy Integration

Greater difficulty in grid voltage control

- In China, the areas where wind farms and PV power plants are grid integrated are mostly at the end of the grid; substantial power changes makes it quite difficult to regulate grid operation voltage, affecting the stability of system voltage.

As wind power output increases rapidly, the bus voltages of Baicheng Grid and Tongfa wind farm drops to 213kV to the minimum, with substantial fluctuation.

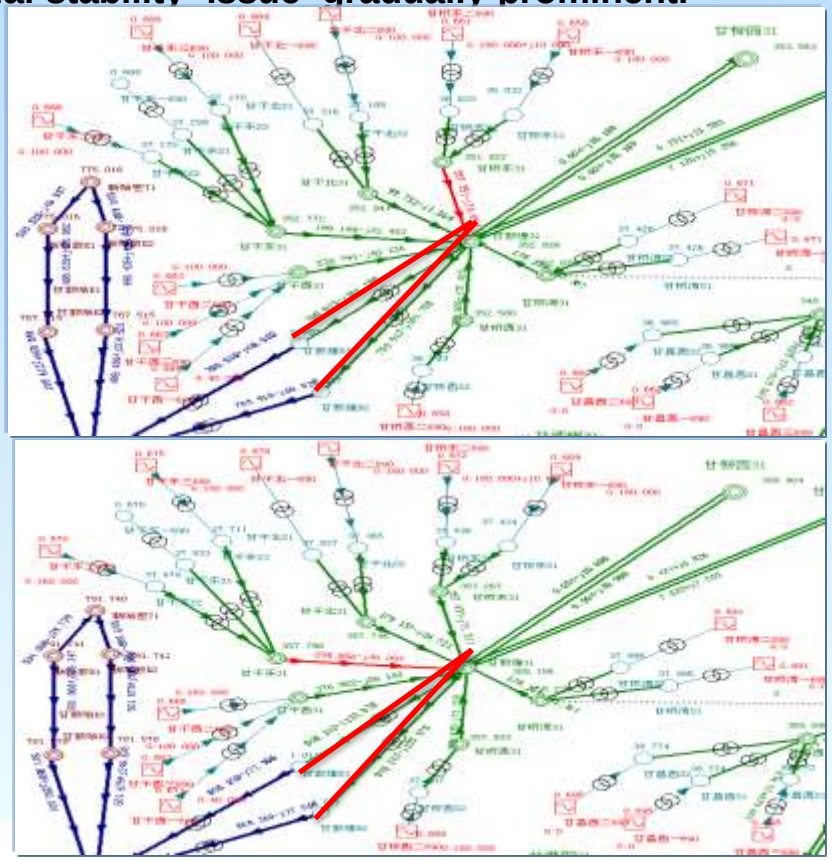


2. Challenges to Grid Operation by New Energy Integration

◆ Proposing challenges to the integration capability of local grids

- When wind farms and PV power plants are connected to the grid in a large-scale manner, the grid will be faced with enlarged transmission flow during large-scale power generation and more heavy-load operation lines, which makes thermal stability issue gradually prominent.

Due to limited capacity for PV power generation currently, such problem is not conspicuous; however, for wind power, it's relatively prominent.



2. Challenges to Grid Operation by New Energy Integration

- **New energy power generation suffers poor anti-disturbance ability which affect the safe operation of the grid.**

- Large-scale new energy grid connection increases risks for stable operation of the grid.
  - Variable system flow, and difficult control over intertie operation;
  - Reduced system inertia and decreased dynamic stability ;
  - Failure to re-establish terminal voltage for new energy power plants after faults, causing voltage instability;
  - As wind power units and PV power generation systems have no capability of LV ride through, in the event of instaneous voltage drop induced by system disturbance, self trip will produce impacts on the system.

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3. Adaptive Requirement of the Grid to New Energy Integration

◆ *Technical Rule for Connecting Wind Farm to Power System GB/T 19963-2011*

- Active power control: all operating units in the wind farm should be capable of achieving continuous smooth regulation on active power and of participating in active power control of the systems. Additionally, they should be able to receive and execute the command to control active power and its changes assigned by dispatch agencies. The recommended values for the change rate of the maximum power of the wind farm are given in the following table.

Installed capacity of wind farm (MW)	Maximum limit of changes to active power in 10min (MW)	Maximum limit of changes to active power in 1min (MW)
<30	10	3
30 ~ 150	Installed capacity /3	Installed capacity /10
>150	50	15

- Reactive power control: wind turbine units in the wind farm should keep the power factor dynamically regulatable in the range of between 0.95 leading or lagging. Specific configuration principles are proposed for reactive capacity of the wind farm. The wind farm should be equipped with reactive voltage control systems and be capable of reactive power regulation and voltage control.

3Adaptive Requirement of the Grid to New Energy Integration

Technical Requirements for Connecting Photovoltaic power plant to Power System GB/T 19964-2012

- Active power control: Medium and large PV power plants should be equipped with active power control systems and be capable of active power regulation. Besides, they should be able to receive and execute automatically the command to control active power and its changes assigned by dispatch agencies of the power systems. The recommended values for change rate of maximum power of the PV power plants are given in the table below.

Installed capacity of PV power plants (MW)	Maximum limit of changes to active power in 10min (MW)	Maximum limit of changes to active power in 1min (MW)
Small	Installed capacity	0.2
Medium	Installed capacity	Installed capacity /5
Large	Installed capacity /3	Installed capacity /10
Note: Reduced output power of PV power plants caused by solar irradiance is beyond limitations above.		

3. Adaptive Requirement of the Grid to New Energy Integration

- ***Technical Requirements for Connecting Photovoltaic power plant to Power System GB/T 19964-2012***

- Medium and large PV power plants should be equipped with reactive voltage control systems and be capable of controlling reactive power and voltage. Specific configuration principles are proposed for reactive capacity of medium and large PV power plants connected to public grids via private lines and collections systems.
- Small PV power plants can be of no capability of regulating reactive power and voltage. When their output active power is 50% higher than their rated power, their power factor should be no less than 0.98 (leading or lagging); while if their output active power is 20~50% higher than that of their rated power, their power factor should be no less than 0.95 (leading or lagging).

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4. Key Operation & Control Technologies for New Energy Grid Integration

Objectives of new energy power generation control

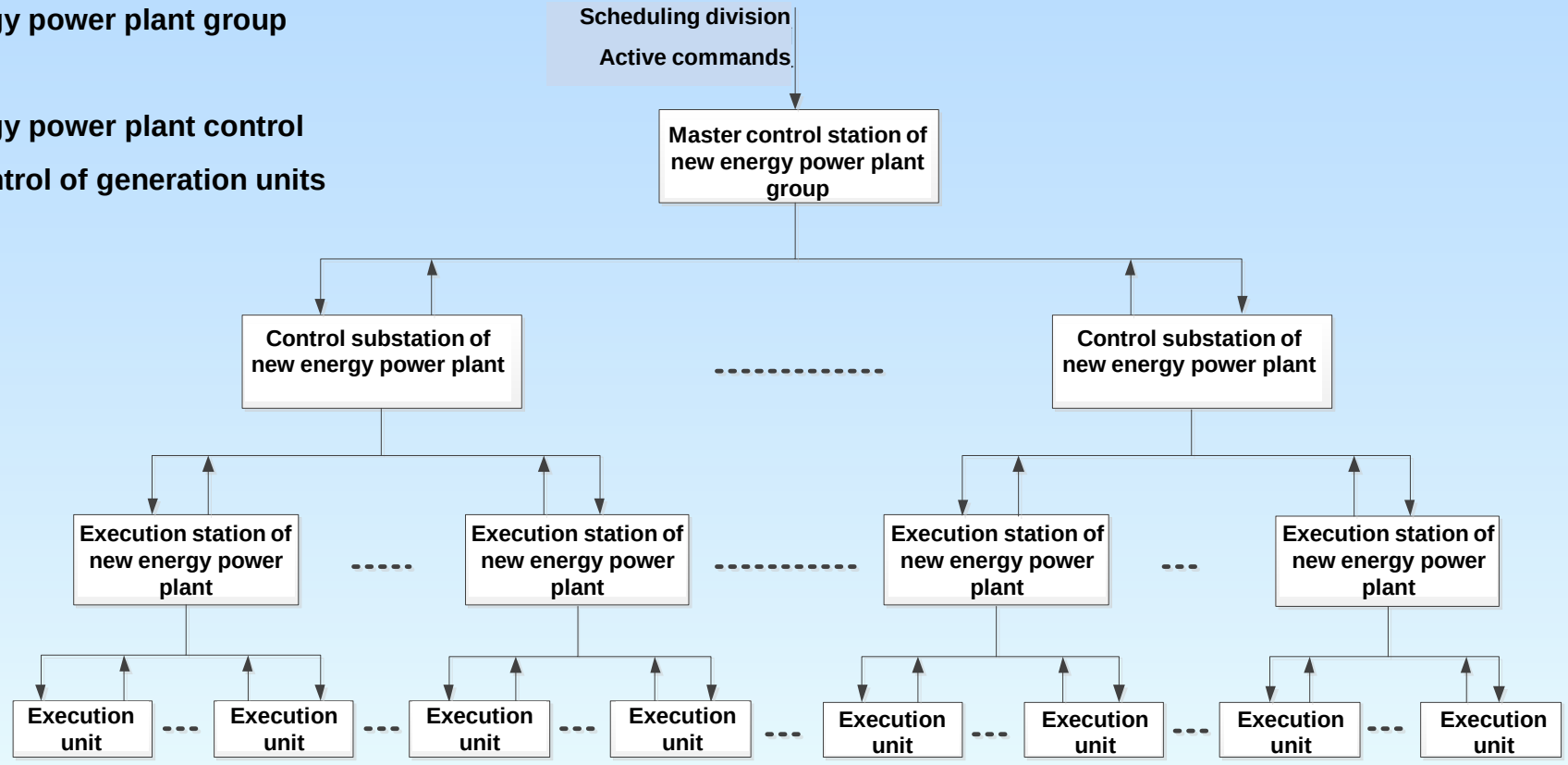
- Satisfy the requirements of relevant standards on adaptability of grid for new energy power station
- Change the extensive control mode of active / reactive power of new energy power plants
- Improve the control accuracy and rationality of active / reactive power of new energy power plants
- Enhance power quality of new energy power plants and avoid possibly trip



4. Key Operation & Control Technologies for New Energy Grid Integration

Active power control related to new energy power generation

- **Control architecture**
  - New energy power plant group control
  - New energy power plant control
  - Active control of generation units

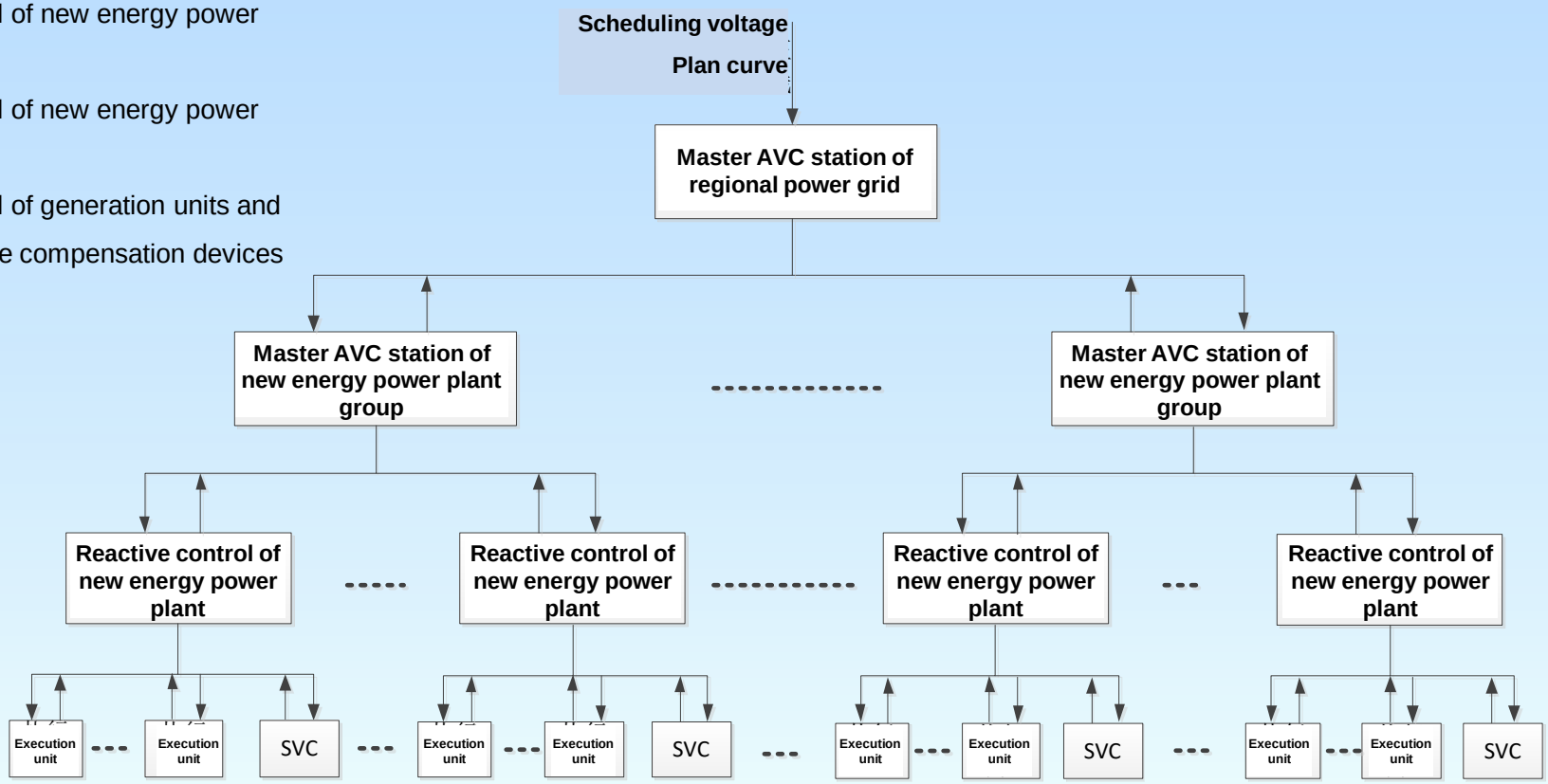


4. Key Operation & Control Technologies for New Energy Grid Integration

Reactive power control related to new energy power generation

Control architecture

- Reactive voltage control of regional grids
- Reactive control of new energy power plant group
- Reactive control of new energy power plant
- Reactive control of generation units and dynamic reactive compensation devices

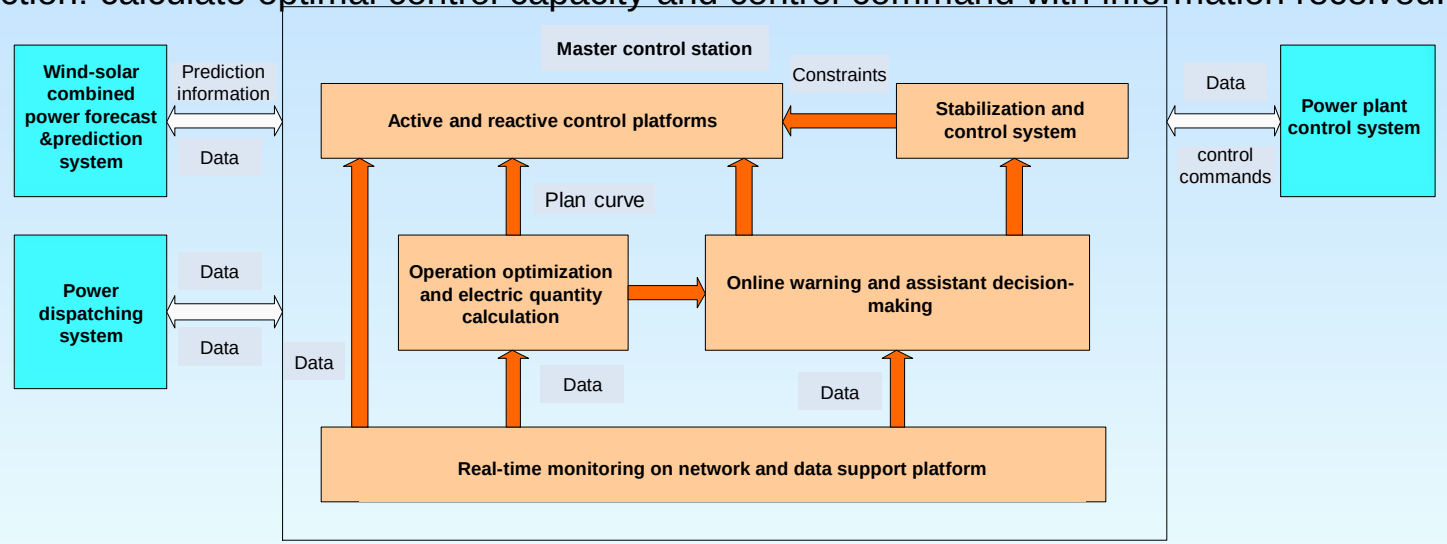


4. Key Operation & Control Technologies for New Energy Grid Integration

New energy power plant group control

Master control station

- Communications: realize seamless integration of forecast data, dispatch commands and management commands through construction of standardized interfaces;
- Configuration: practise integrated control of active frequency, reactive voltage, and safe and stable control;
- Function: calculate optimal control capacity and control command with information received.

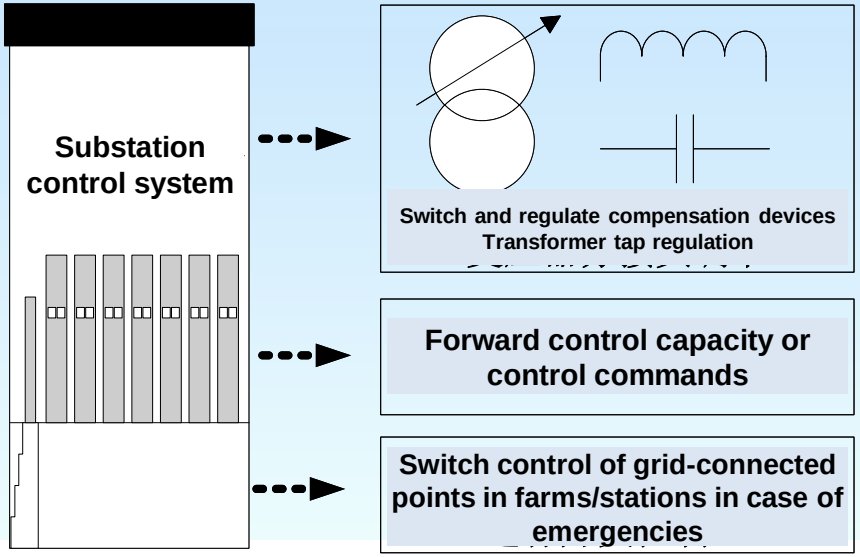


4. Key Operation & Control Technologies for New Energy Grid Integration

New energy power plant group control

Substation control

- Communications: receive control capacity / control command and upload operating status information of the new energy power plants / generation units;
- Configuration: The control objects are main transformer tap of the booster station, reactive compensation devices, wind farms, PV power plants; etc. ;
- Function: the control commands of the master receiving stations regulate reactive compensation devices and the main transformer taps as well as emergency cutting; they also function to decompose the control capacity transmitted by the master station and send it to power plants.

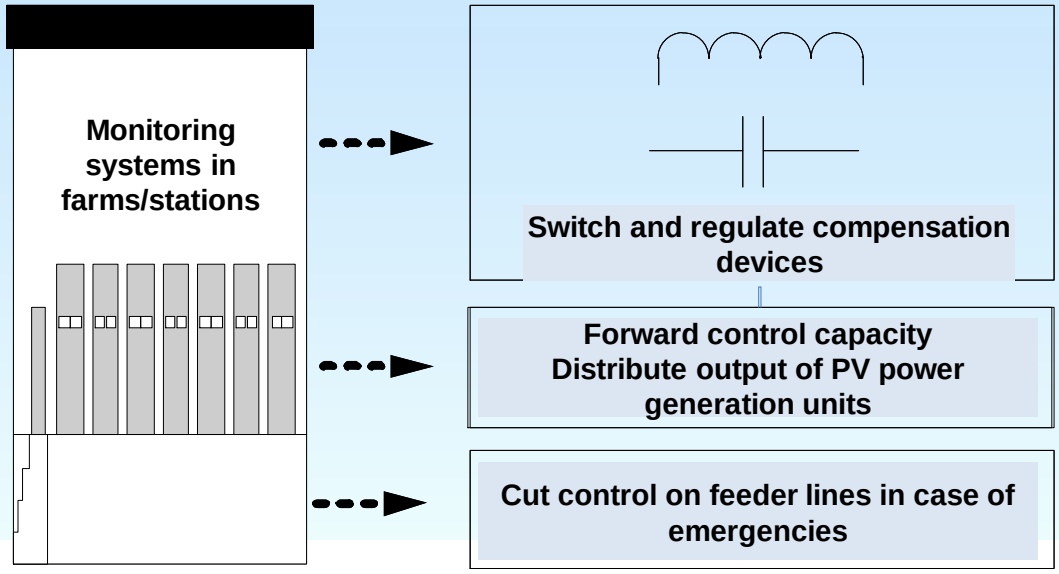


4. Key technologies on Grid-connected Operation Control of New Energy

New energy power station group control

Execution station of new energy power plant

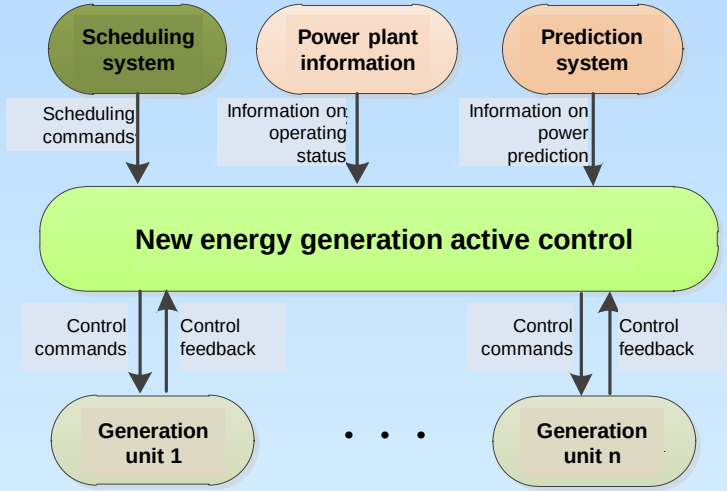
- Communication: forward control command and upload operating status information of new energy power plants / generation units ;
- Configuration: Control objects are mainly reactive compensation devices, PV power generation units, wind turbine units, etc.;
- Function: receive operating information of the monitoring systems in farms/stations and upload it to the control sub-station; receive and execute control commands transmitted by control substations, and regulate PV power generation units as well as switch and regulatie local compensation devices.



4. Key technologies on Grid-connected Operation Control of New Energy

Active power control of new energy power plant

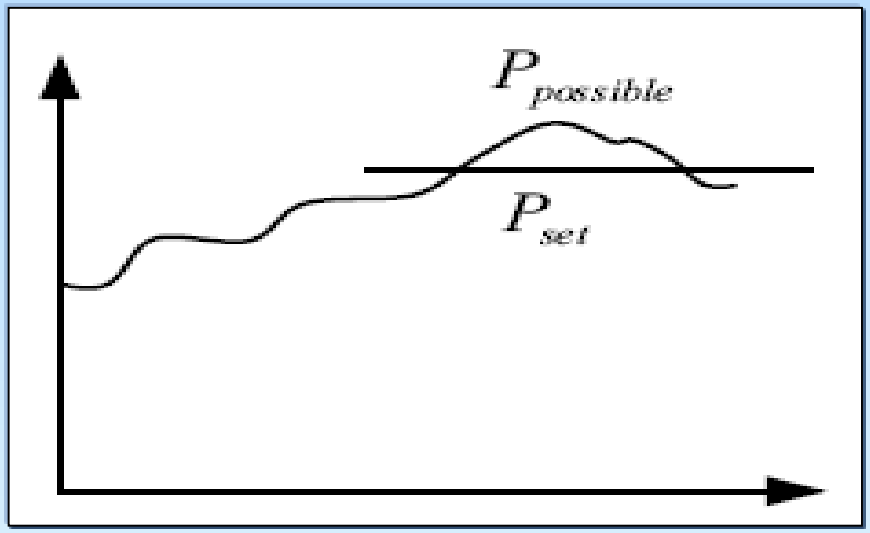
- **Control principles**
  - Satisfy the requirements for active control performance indicators of new energy power plants by grid scheduling divisions
  - Based on the actual operation properties and power forecast information of new energy power plants
  - Coordinate generation units with various regulation performances
- **Control objectives**
  - Track power generation plan commands issued grid scheduling divisions
  - power generation benefits of new energy power plants
- **Control objects**
  - Wind turbine generator units
  - PV inverters



4. Key technologies on Grid-connected Operation Control of New Energy

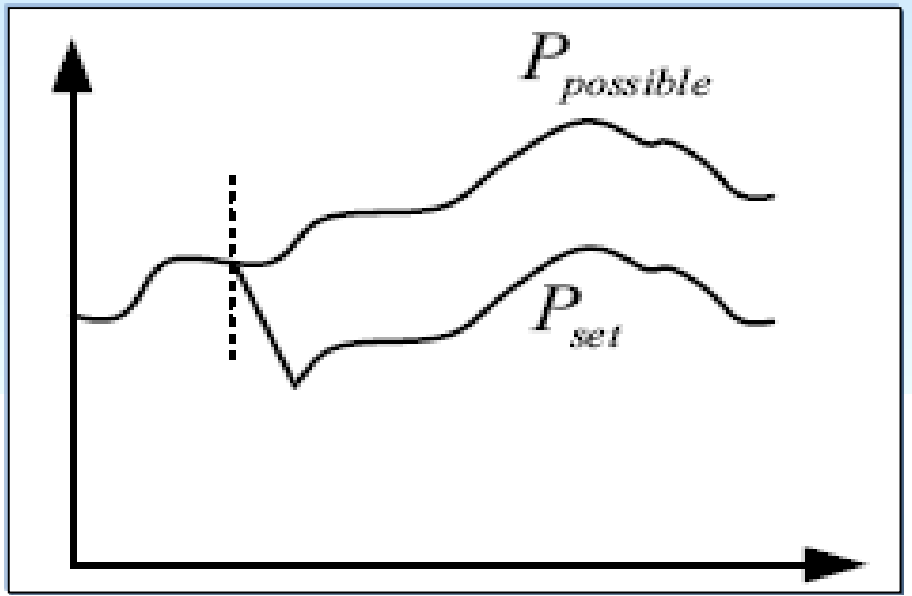
◆ Active power control of new energy power plant

➢ Control architecture



1. Limit mode: Active control system of new energy power plants shall control the output of power plants below preset limit or the limit issued by dispatching agencies; the limit values can be given in different time slots.

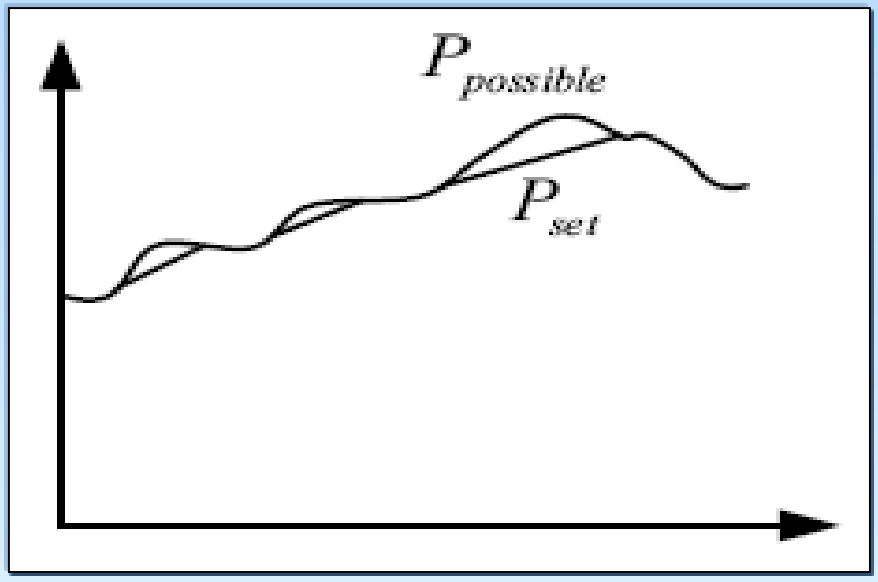
2. Difference mode: there's power difference between the output of new energy power plants and the forecasted power of wind farms. Such power difference is pre-set value, or the value issued by the dispatching agencies, which is equivalent to reserving certain active power regulation margin for the stations.



4. Key technologies on Grid-connected Operation Control of New Energy

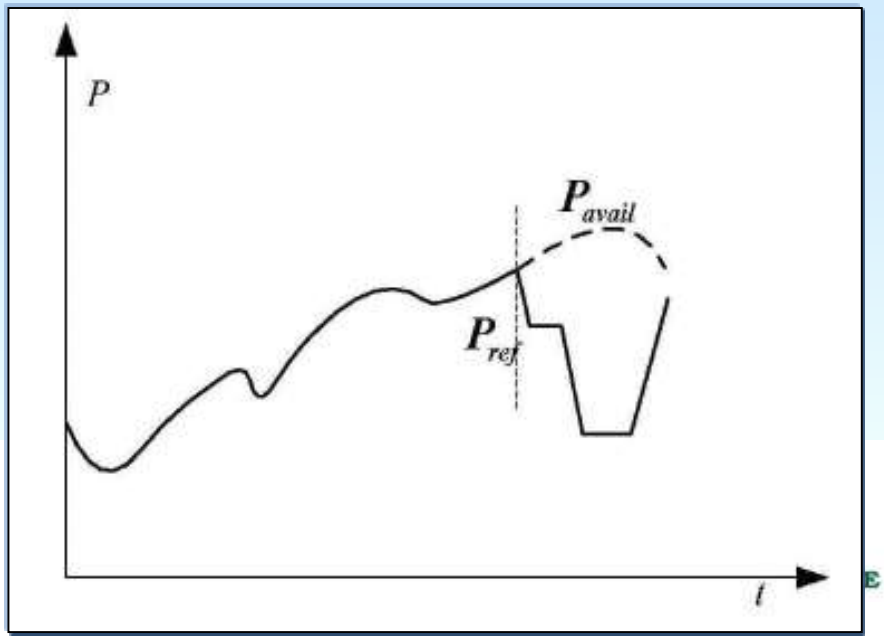
◆ Active power control of new energy power plant

➢ Control architecture



3. Slope mode: the changes of the output of new energy power plants must be within the given slope in each control cycle. The overall output power of the wind farms should follow the given power of the power plants on condition that the slope is satisfied.

4. Balance mode: under conditions of limited power change rate, the active power control system of new energy plant should immediately adjust its output to the power limit given by grid dispatching agencies (if the given value is greater than the maximum power, it can be adjusted to the maximum generatable power) .

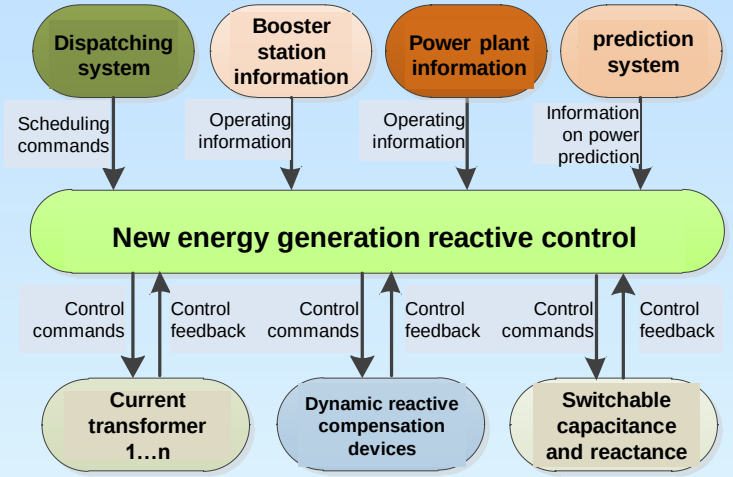


4. Key technologies on Grid-connected Operation Control of New Energy

Reactive power control of new energy power plant

Control principles

- Satisfy the requirements for reactive control performance indicators of new energy power plants raised by grid dispatching divisions
- Based on actual operation properties and power forecast information of new energy power plants
- Comprehensive utilization of inverters, dynamic reactive compensation and other reactive sources
- Consider coordination between static and dynamic reactive controls



Control objectives

- Track voltage curves or reactive commands issued by grid dispatching divisions
- Improve energy quality of new energy power plants

4. Key technologies on Grid-connected Operation Control of New Energy

◆ Reactive power control of new energy power plant

➢ Control targets

■ Power generation unit AC devices

For new energy power generation units (such as double-fed wind turbine units, direct-drive wind turbine units, PV inverters) that are connected with the grid through current transformers , in theory, as long as the capacity of current transformers allows, the generation units themselves are capable of providing reactive power; however, early asynchronous wind power generation units have no such capability.

■ Reactive compensation devices

In accordance with national standards, to meet reactive demand of new energy power plants, all the power plants should be equipped with corresponding reactive compensation devices. The reactive compensation devices in use now are mainly two types, namely, SVCs (Static Var Compensators) and SVGs (static synchronous compensators) .

4. Key technologies on Grid-connected Operation Control of New Energy

◆ Reactive power control of new energy power plant

➢ Control pattern

■ Real-time voltage control pattern

Take voltage dispatching commands in real time from higher-level and control and maintain the voltage of grid-connection points of new energy power plants around the command value.

■ Reactive power control pattern

It controls the power output of wind farms or PV power plants no more than the specified limit. The limit value can be set.

■ Power factor control pattern

Fixed deviation (limit) are always kept between PV output power and the maximum adjustable output, which can be regarded as a means for PV power plants to participate in active reserve of the system.

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5 Conclusion and Outlook

◆ Conclusion

➢ Active power control of new energy power plant

In a long-term viewpoint, controllable operation of new energy power plants and integrate it into the dispatching system of the grid is the development trend of safe grid-integrated development. Therefore, the generation management of new energy power plants will become an important research direction in the field of new energy grid-connection control. With improved technologies of active control related to new energy generation, it will lead to enhanced new energy grid-connection capacity, better grid damping characteristics, as well as continuously improved ability of new energy power plants to actively participate in grid regulation. To improve the dispatching ability of new energy power generation and promote the operating mode of new energy power plants to develop towards the way the conventional power plants does, will significantly improve operating mode, power generation plans as well as security and stability of the power system of the grids that accomodate large numbers of new energy power plants.

5 Conclusion and Outlook

◆ Outlook

➢ Reactive power control of new energy power plant

Since new energy power plants are located at the end of the grid, substantial changes to the output is bound to cause larger fluctuations in the grid voltage and thus affect the stabilization of grid voltage; it will impose greater threats on secure and stable operation of the new energy power plants themselves. Therefore, it's a must to require new energy power plants to carry out reactive voltage control which is also urgently needed for the development of new energy plants themselves. One of the major pattern to develop new energy power generation in China is to build up large new energy generation bases with centralized long- distance transmission. Adopting a master and coordinated reactive voltage control strategy for new energy power generation bases is a necessary way out for China's new energy power generation.


End
Thanks