Grid Impacts and Technical Challenges for the Bulk Power System

Integrating with Large Renewable Energy

Dr. CHI Yongning

Chief Engineer, renewable energy research center, CEPRI

Secretary, IEC SC 8A – Grid Integration of RE Generation

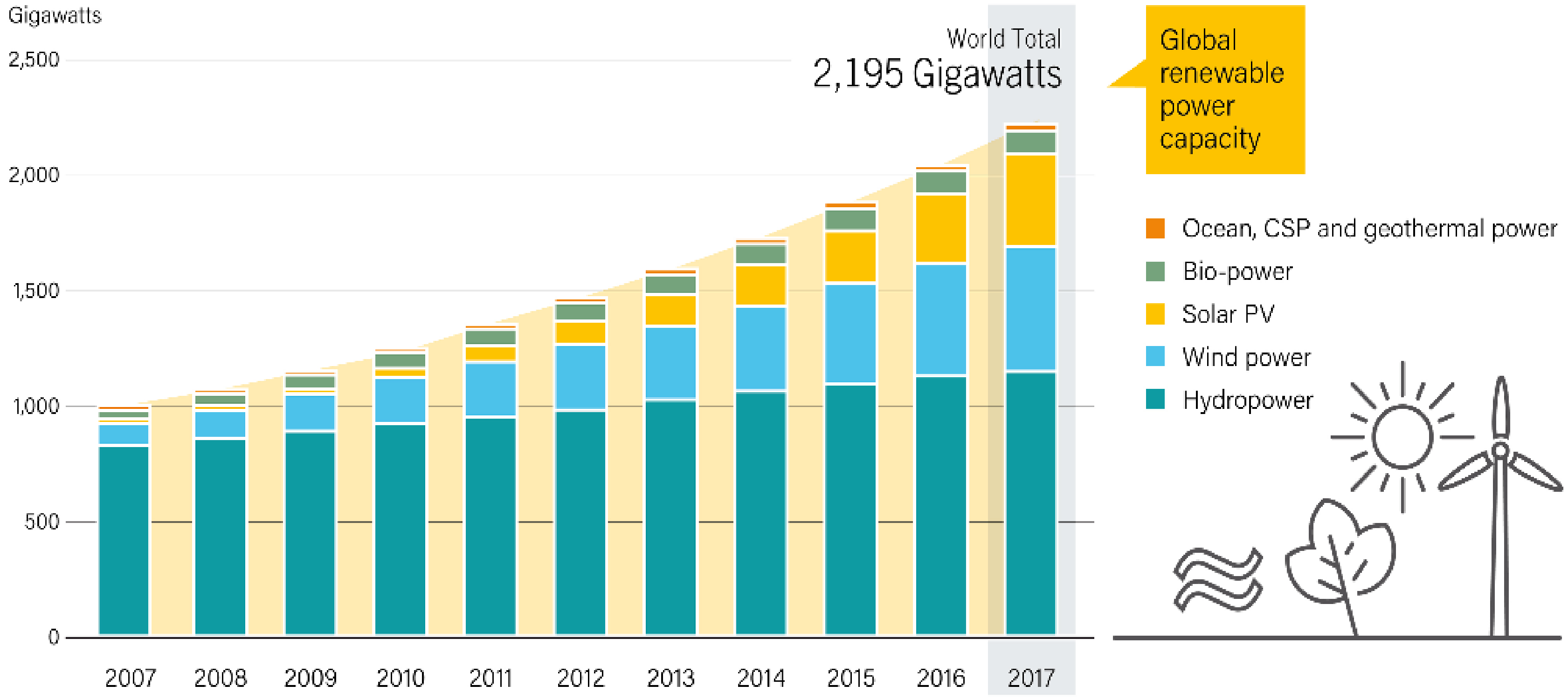
5 December, 2018 Aalborg, Denmark

IEEE

1. Grid impact of RE on power system

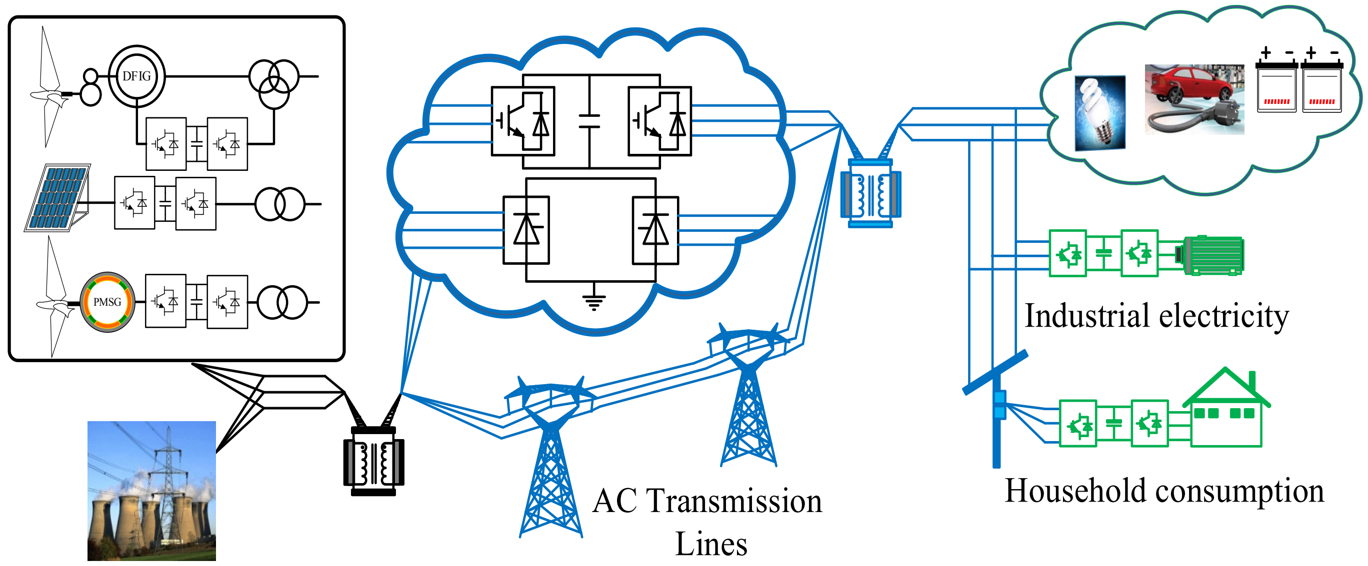
- RE Capacity: 1081 GW total (not including hydro) , 2195 GW total (including hydro) by the end of 2017;
- 178 GW capacity added in 2017, 84% new added capacity came from wind and solar power.

Global Renewable Power Capacity, 2007-2017



■ Source: REN 21 Renewables 2018 Global Status Report

1. Grid impact of RE on power system

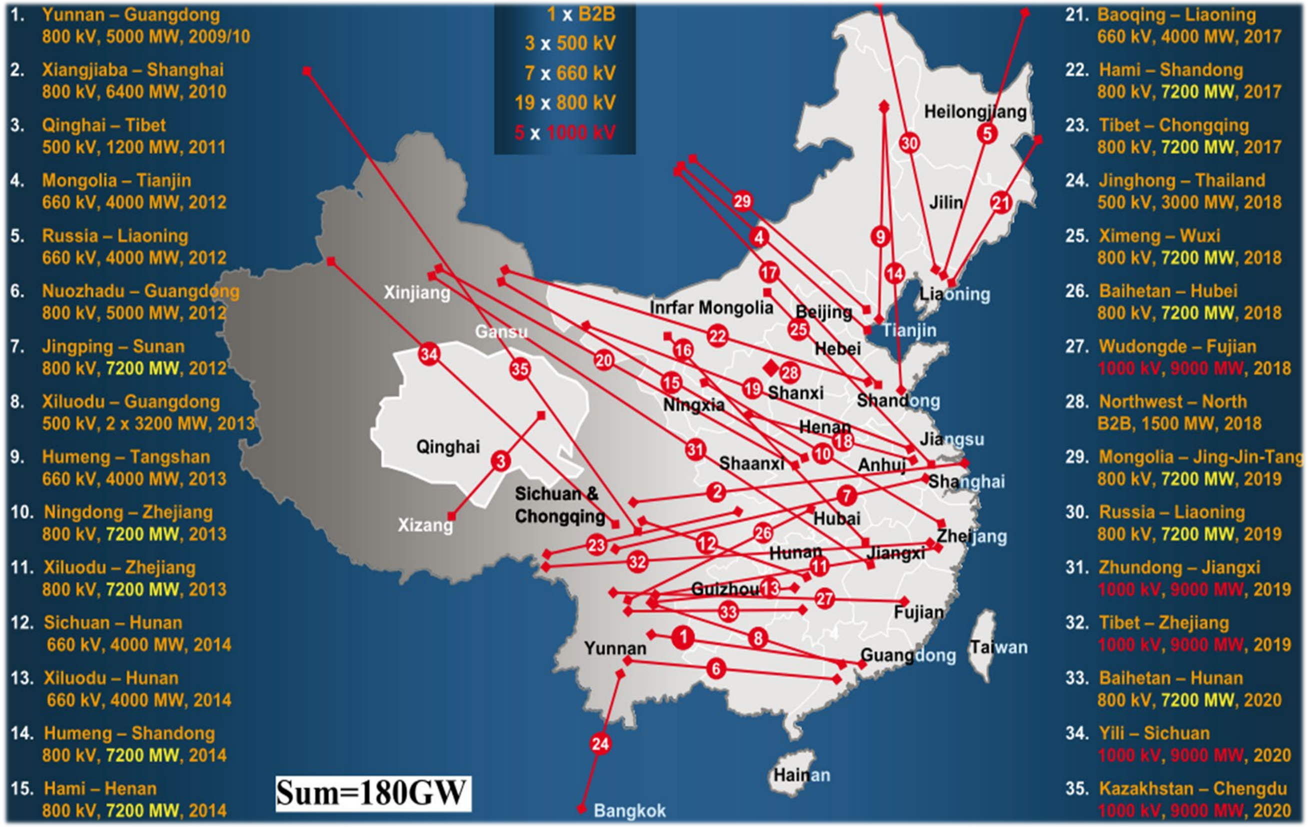


1. Weak AC Grid Connection
2. Short circuit ratio
3. Low Inertia
4. Controllability
5. New stability issues

- Power converters have been massively used in grid-connections for RE generations, LCC/VSC HVDC transmissions and variable-frequency AC drives (i.e., electrified transportations).
- Compare with traditional power systems dominated by synchronous machines, nowadays, the power system performances are dramatically changed.

1. Grid impact of RE on power system

- Many super/ultra-HVDC transmission lines for power delivery with 180 GW capacity, for delivering coal, hydro, and RE generations.
  - ✓ Hami-Henan, ±800kV, 8000MW, >2000km
  - ✓ Zhundong-Jiangxi, ±1000kV, 8000MW, >3000km



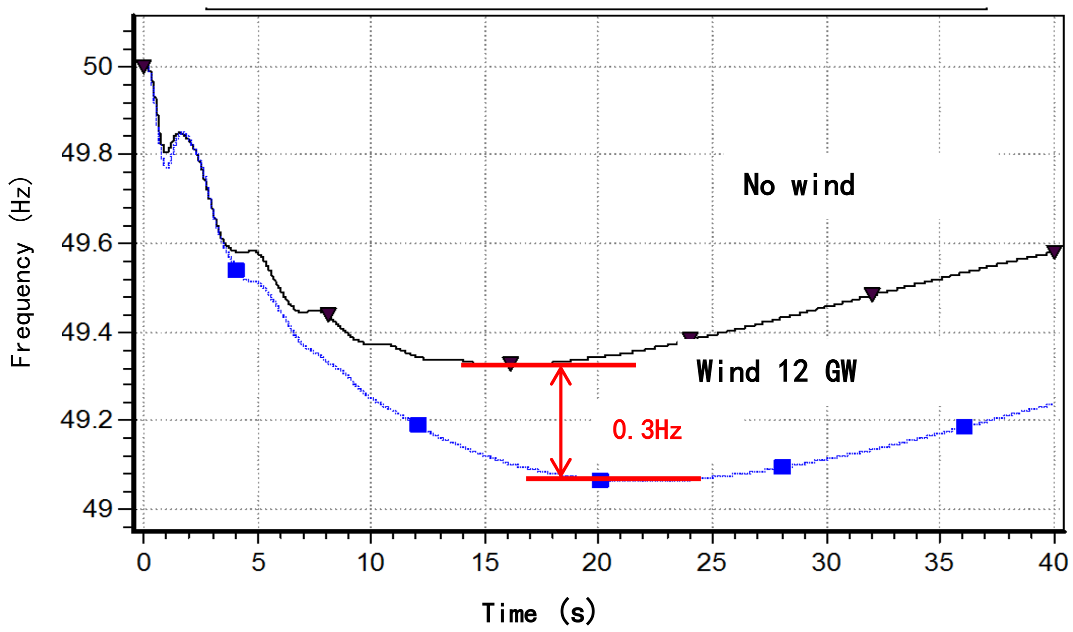
Super-/Ultra- HVDC Projects in China till 2020

- **Highly-Penetration RE and Long-Distance HVDC Transmission** are the main features for China power grid, which will significantly change the system dynamic performance.

IEEE

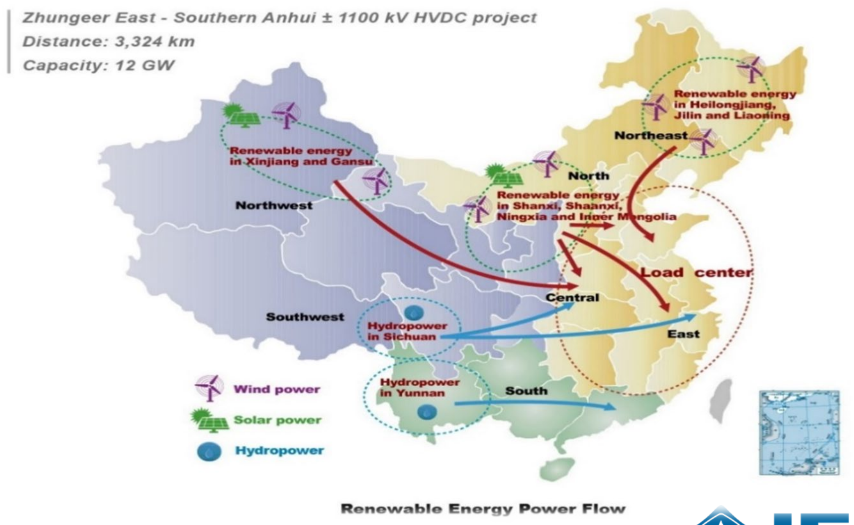
1. Grid impact of RE on power system

- With the proportion of RE increasing, conventional power sources are largely replaced by RE, in some provinces more than 30% of total installed power are RE, system's inertia and frequency regulation capability continue to decrease.



The Northwest Power Grid loses 3.5 GW power at a load level of 68 GW. If there is no wind power in the network, the system frequency drops will be 0.65 Hz. If the wind power output reaches 12 GW, the frequency drops will be 0.95 Hz.

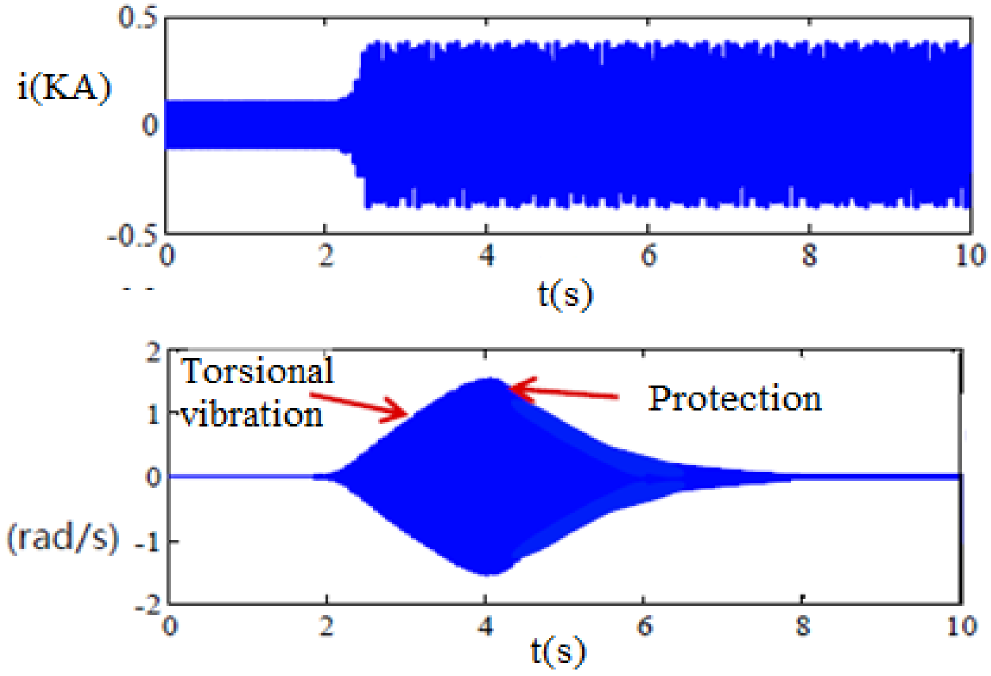
province	Wind power capacity (10MW)	PV capacity (10MW)	Renewable energy ratio（%）
Ganshu	1277	778	42.8
Ningxia	942	613	39.3
Qinghai	101	785	36.6
Xinjiang	1806	935	34.0

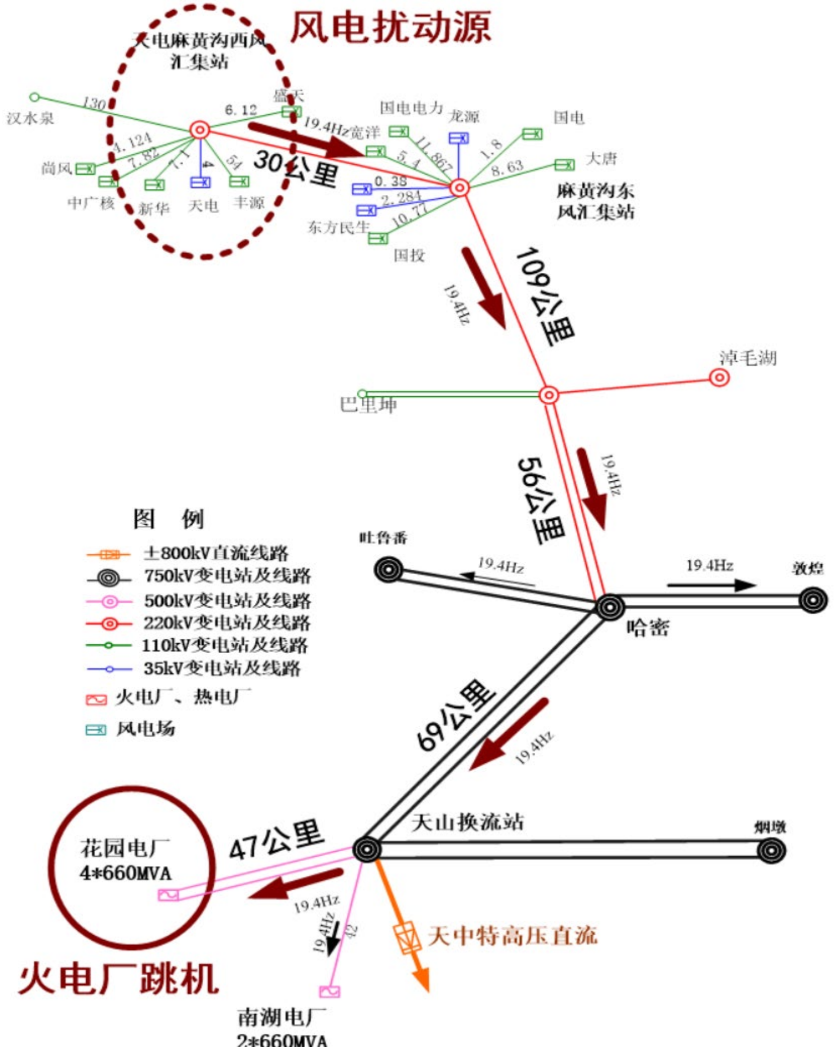


1. Grid impact of RE on power system

□ Sub-synchronous Oscillation in Hami, Xinjiang，2015

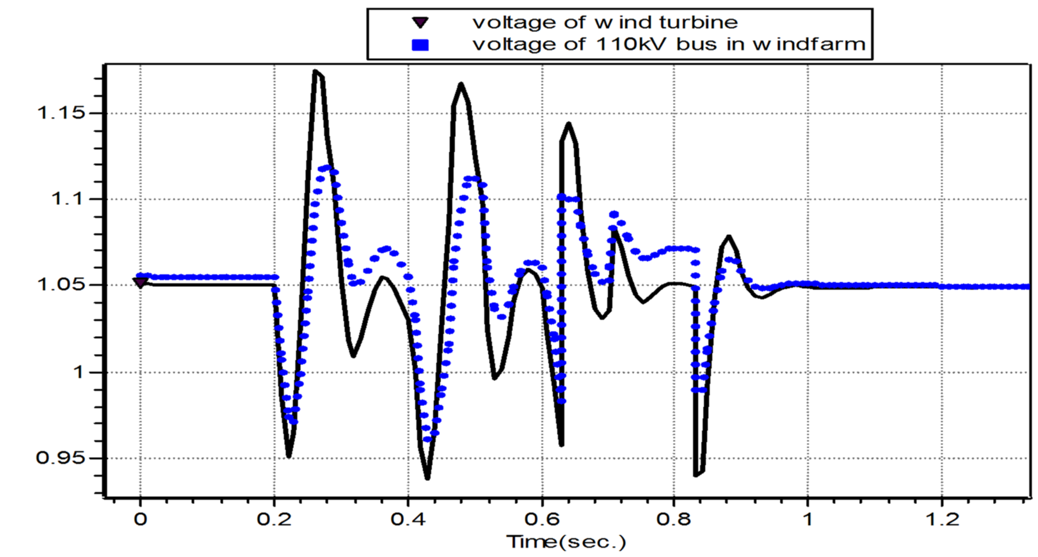
✓ On July 1, 2015, the wind generation in Xinjiang Hami continued to produce sub-synchronous currents, causing interaction on adjacent synchronous machine shaft, torsional vibration protection in huayuan Power Plant triggered leading to a tripping of 660 MW unit (3 Units).





1. Grid impact of RE on power system

- **Increased risk of wind power outage due to the commutation failure of UHVDC systems. (Wind turbine not with HVRT capability)**
  - ✓ During the commutation failure of UHVDC from Hami to Zhengzhou (Tianzhong UHVDC) and from Zalut to Qingzhou, the transient overvoltage of the power grid at the sending end could reach 1.2-1.3pu, which will cause large-scale renewable energy generation tripping.



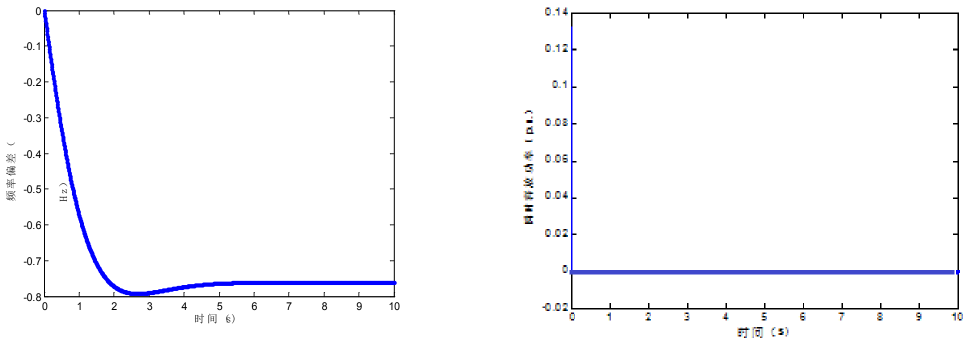
1 Grid impact of RE on power system

2 Technical issues and Solutions

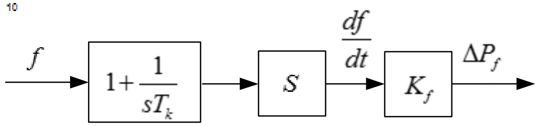
3 Technical trend and conclusions

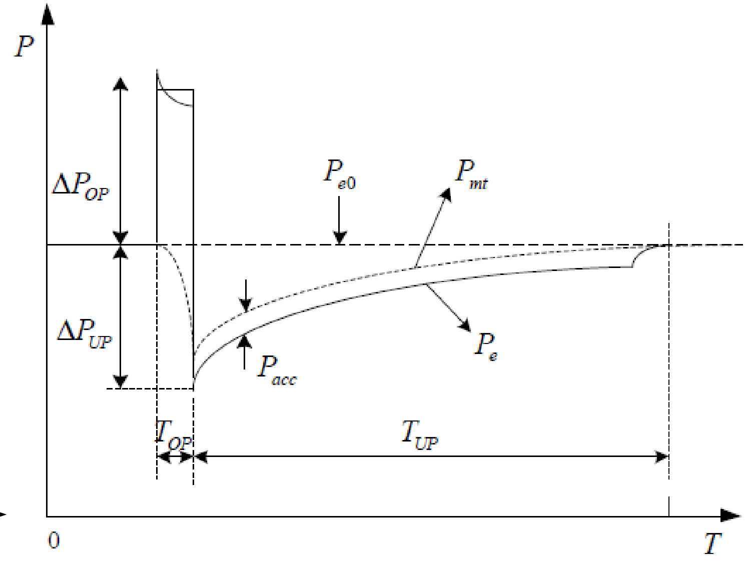
2.1 Technical Challenges and Solutions - Frequency control

☐ Inertia Response Characteristics of Renewable Energy



Frequency response

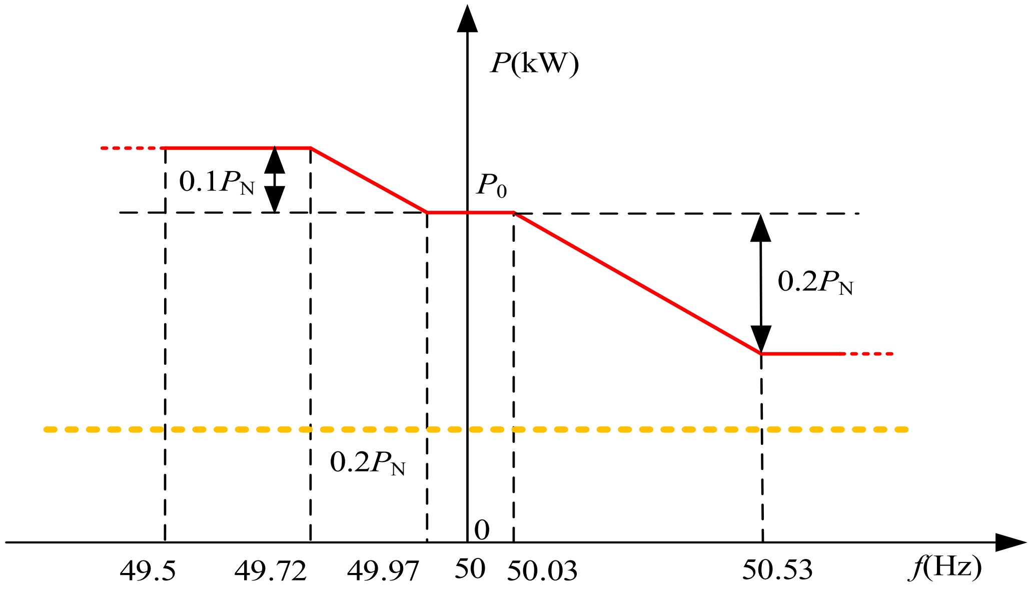


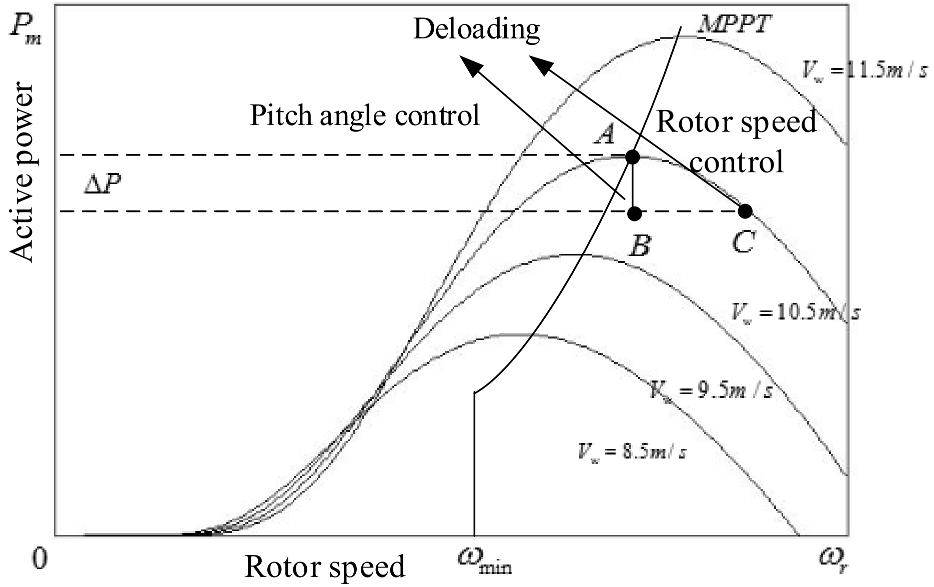


- ✓ Variable speed wind turbines converter control decouples the active power from the system frequency, the wind turbines not capable of responding to the frequency change of the power grid, and the rotational kinetic energy is “hidden”.
- ✓ The renewable energy generation utilizes additional virtual inertia control to provide fast active power support using stored kinetic energy in the rotating mass to respond the system frequency changes, but it is not sustainable.

2.1 Technical Challenges and Solutions - Frequency control

Primary frequency control for renewable energy generation

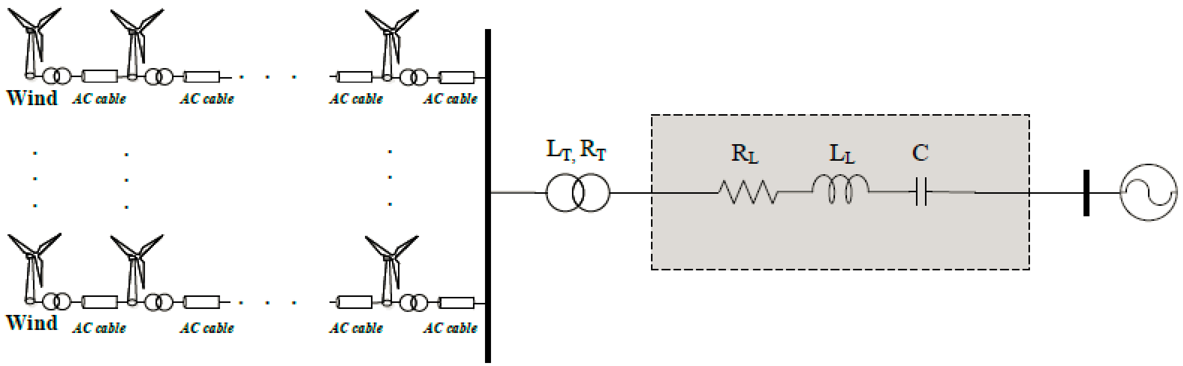




- ✓ When the system frequency deviation value is larger than the primary frequency control's dead zone, the renewable energy could adjust the active power output according to the frequency deviation and participate in the power grid primary frequency control. The control speed can be faster than the conventional generation.

2.2 Technical Challenges and Solutions - SSR/SSO

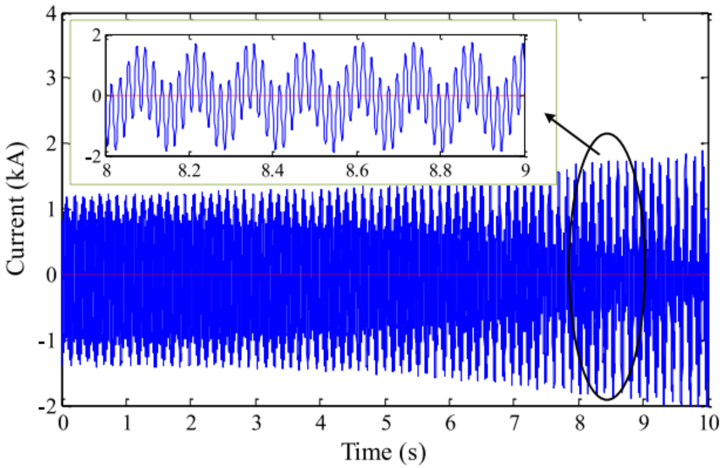
- **Sub-synchronous Oscillation - wind connected to high series-compensated system**

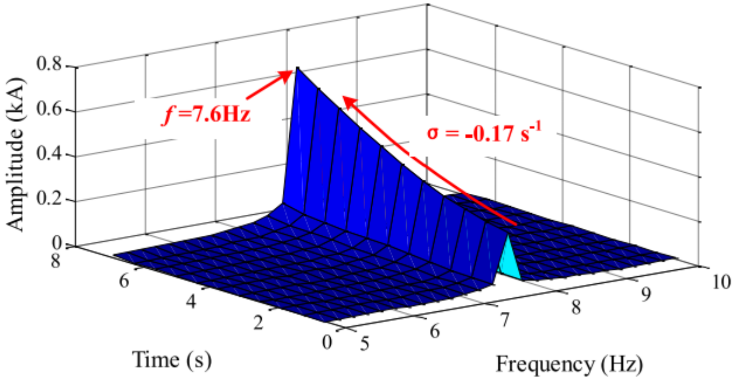


- The SSO frequency is determined by the parameters of the wind turbine controller and the parameters of the transmission system.
  - ✓ Wind turbine behaving as a negative resistance effect
  - ✓ The SSO is likely to occur when the series-compensated degree is high
  - ✓ It is easy to occur when the wind power output is low.
- Solution - After the fault and oscillation is detected, bypassing a set of series compensation, or adding SSO suppression strategy.

2.2 Technical Challenges and Solutions - SSR/SSO

◻ Sub-synchronous Oscillation - wind connected to high series-compensated system



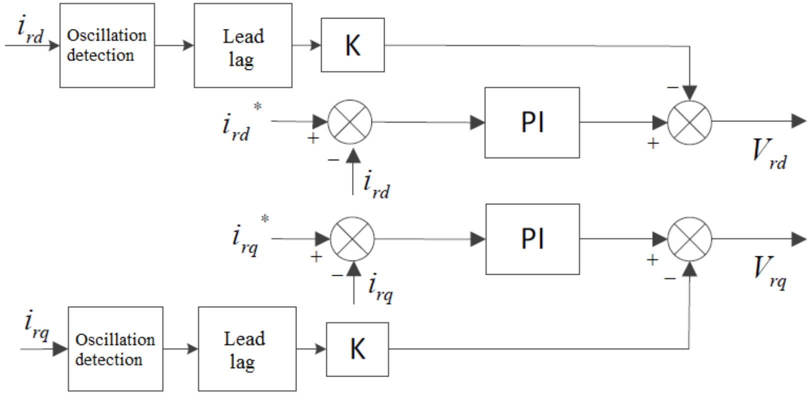


Field measured current and its DFT result at Guyuan substation.

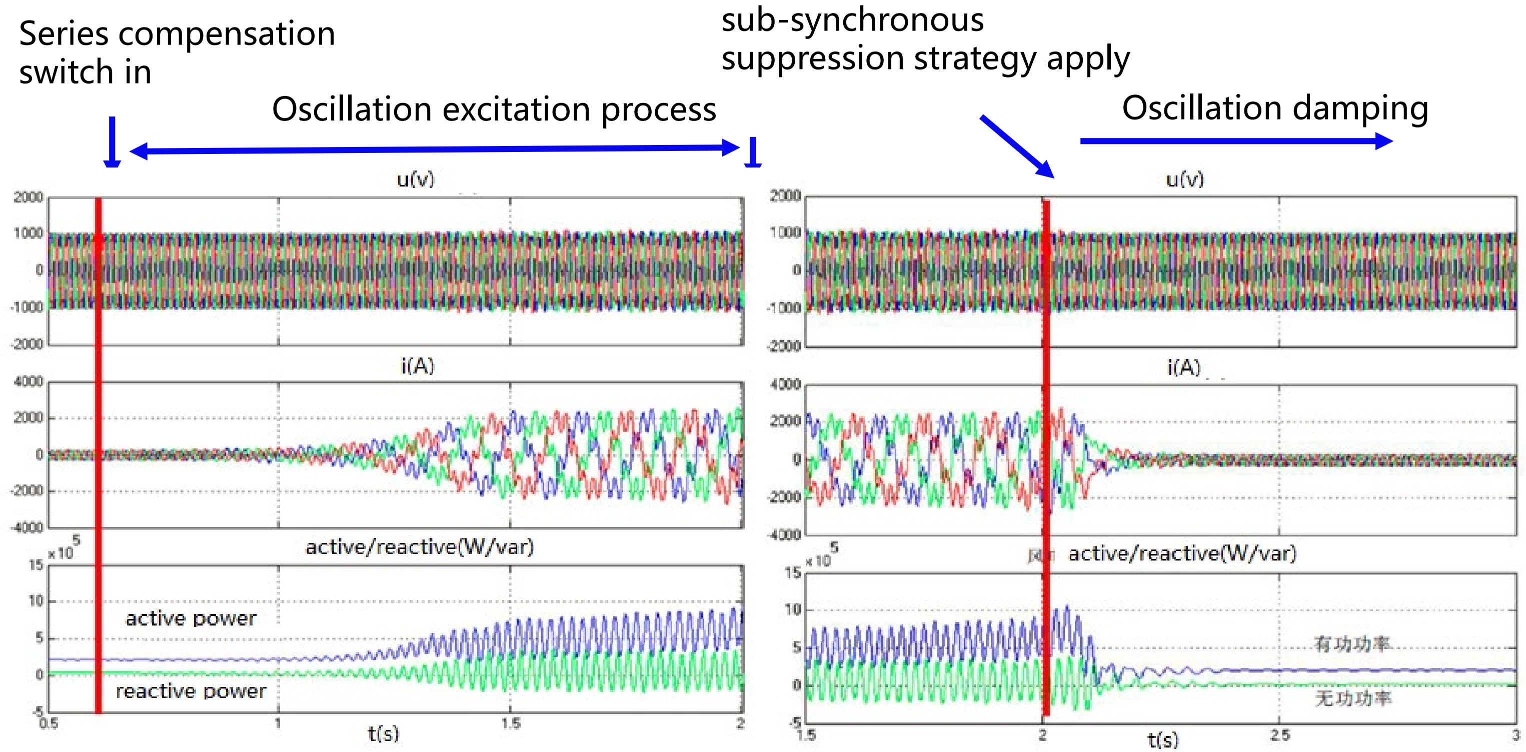
- ◻ **A SSO event occurred on December 25, 2012 in Guyuan, China. The oscillation frequency is at 7.6 Hz and the damping is $-0.17\ s^{-1}$.**
- ◻ **Negative resistance effect :**
  - ✓ A negative slip at the SSO frequency leads to a negative equivalent rotor resistance (IGE).
  - ✓ Interaction between RSC and grid, negative damping (SSCI).

2.2 Technical Challenges and Solutions - SSR/SSO

☐ Additional oscillation suppression control strategy in wind turbine



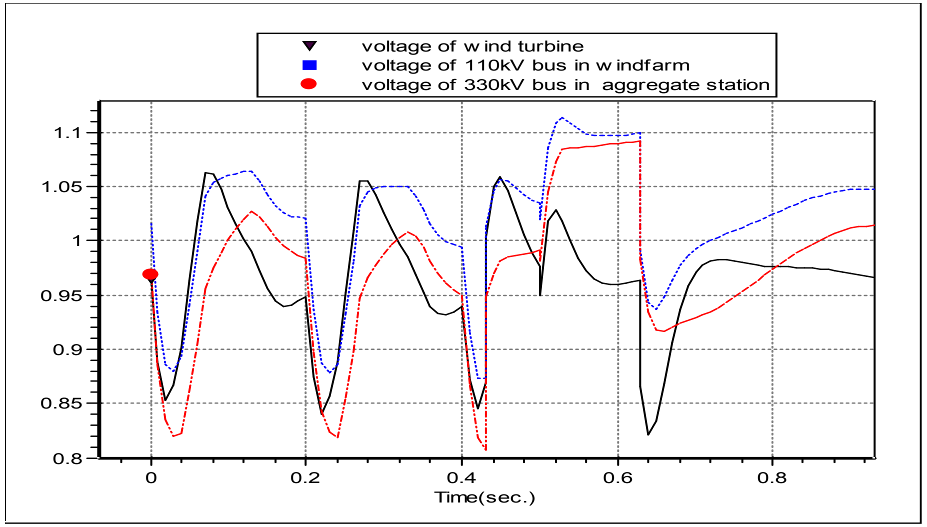
Control diagram of the virtual resistor for wind turbine

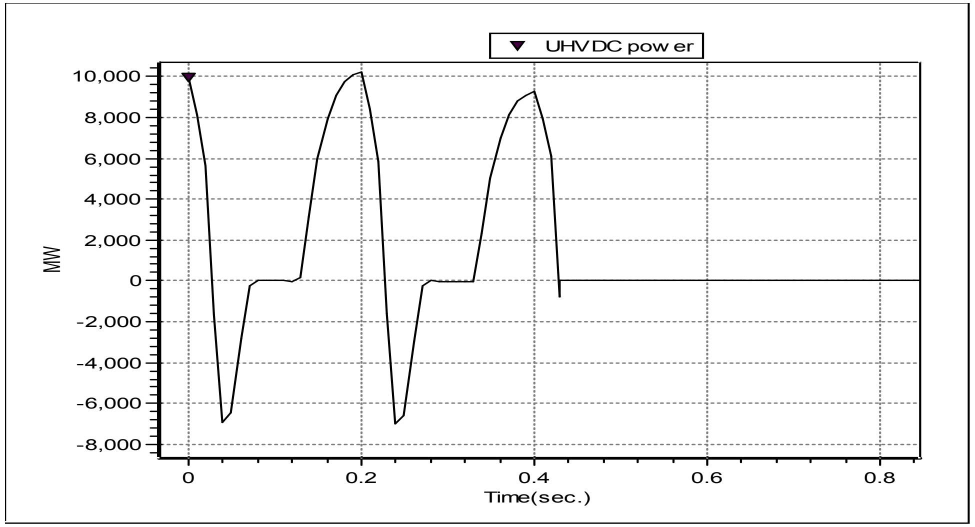


2.3 Technical Challenges and Solutions - HVRT

☐ HVDC commutation failure incurred high Voltage process

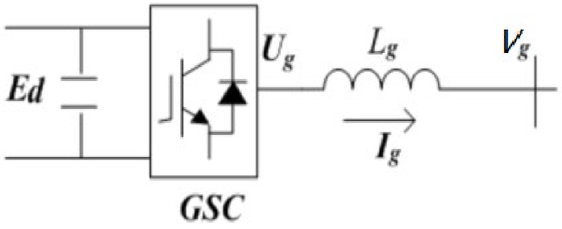
- ✓ Stage 1 (Low voltage): The commutation failure causes the DC current rise rapidly, resulting in the AC voltage drop.
- ✓ Stage 2 (High voltage): the DC current decreases, and the inverter reactive power consumption decreases, and there is an transient overvoltage on AC system.
- ✓ Stage3 (Voltage recovery): DC power gradually recovers to pre-fault level, converter reactive power consumption gradually increases, reactive power are gradually balanced.



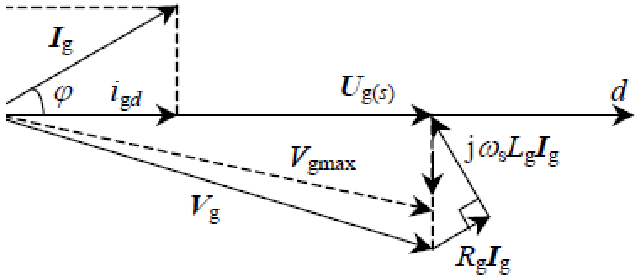


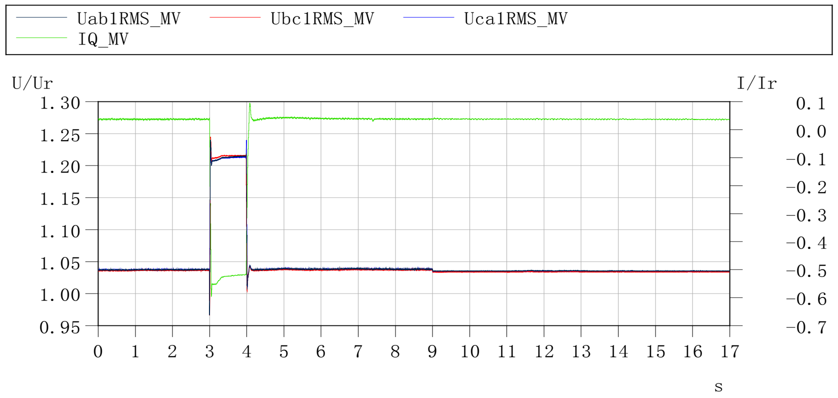
2.3 Technical Challenges and Solutions - HVRT

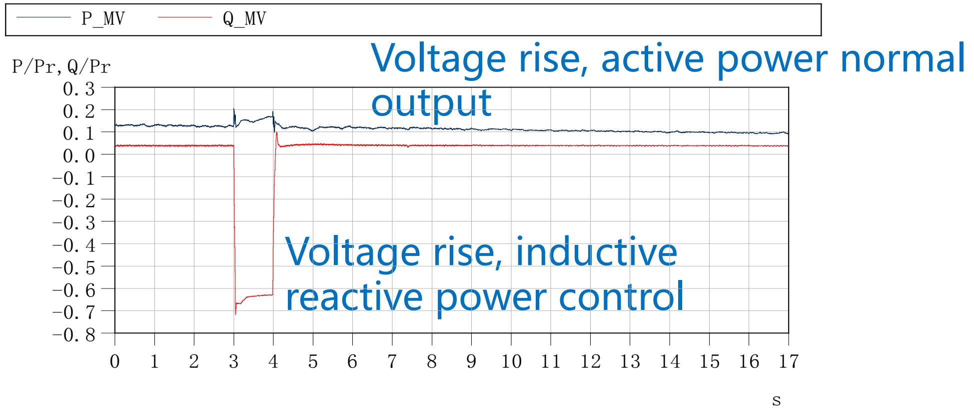
□ High Voltage Ride Through - Technical Measures



- ✓ Auxiliary equipment such as wind turbine pitch control system, power supply and protection system meet the requirements of withstanding voltage (HVRT).
- ✓ During the grid high voltage period, the converter absorbs the inductive reactive power. By controlling the voltage vector of the equivalent inductance on the grid side, the voltage of the DC side and the converter power devices is much lower than grid voltage.







HVRT Measured Curve of Wind Turbine

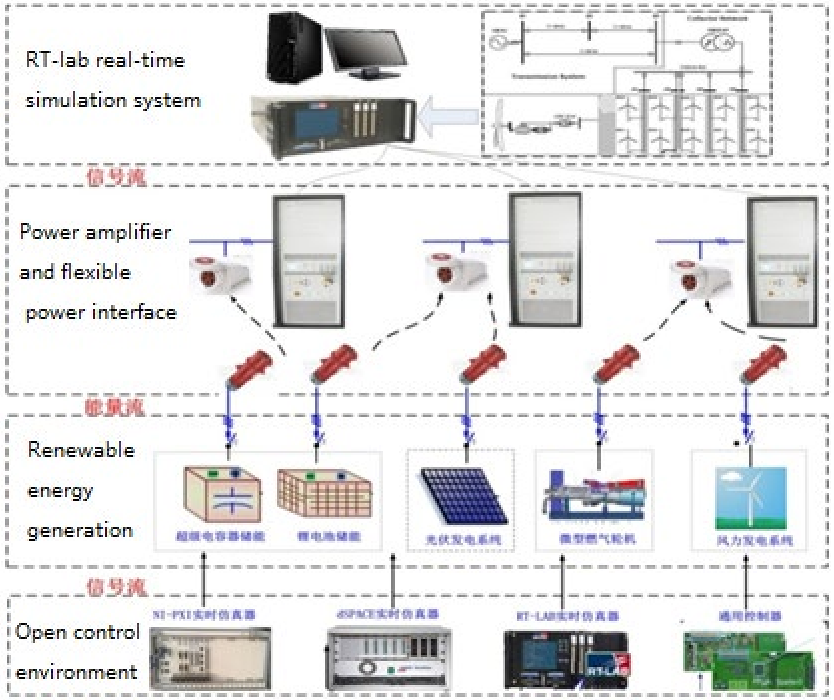
1 Grid impact of RE on power system

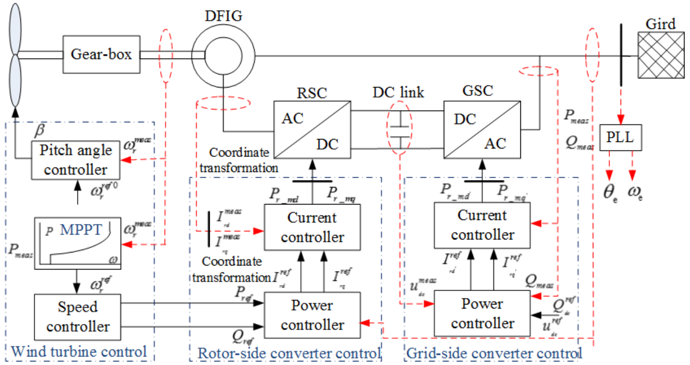
2 Technical issues and Solutions

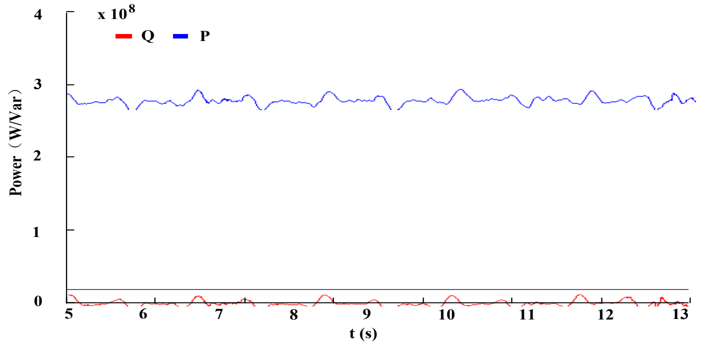
3 Technical trend and conclusions

3.1 Technical trends

◻ Digital-analog hybrid simulation platform and modeling (HIL)



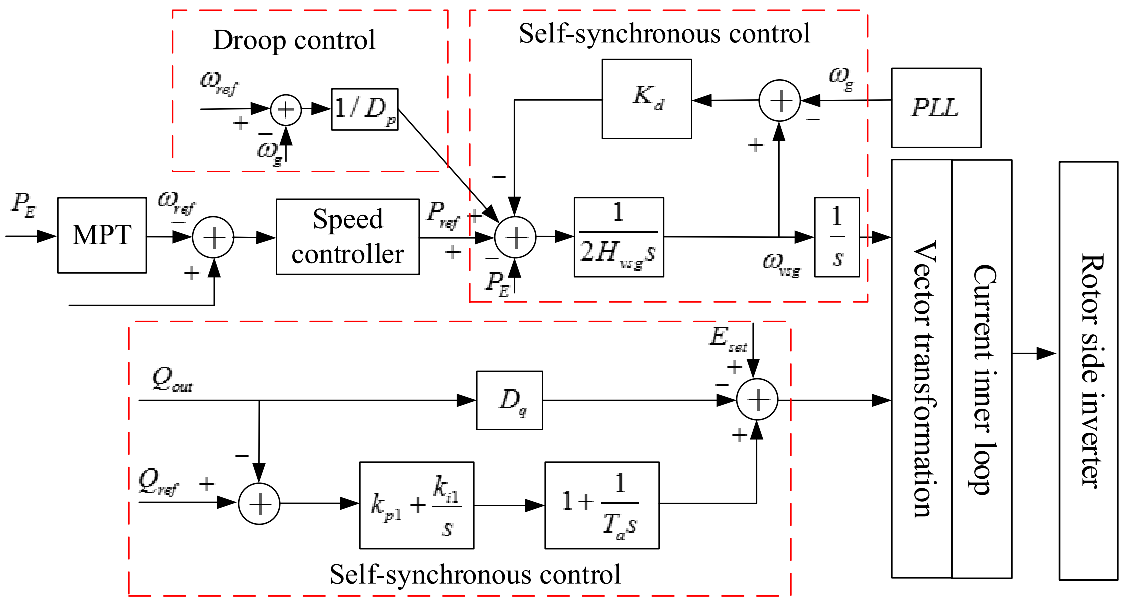


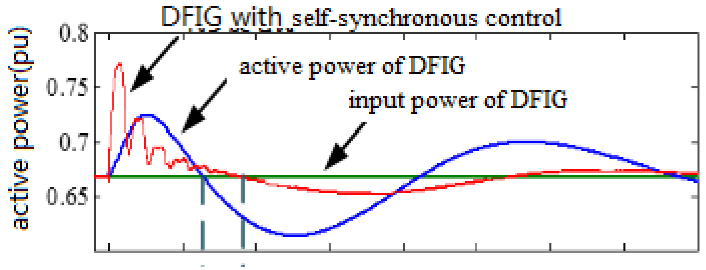


- ✓ Open renewable energy generation control strategy development and verification environment. The generation unit could be flexible plugging in and off.
- ✓ Building the renewable energy generation modeling ‘digital-analog hybrid simulation, dynamic library modeling, Electromechanical modeling, Field test’.

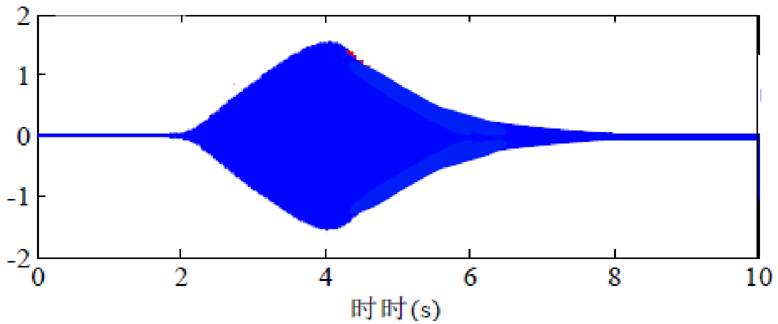
3.1 Technical trends

□ VSG and its implementation





frequency response



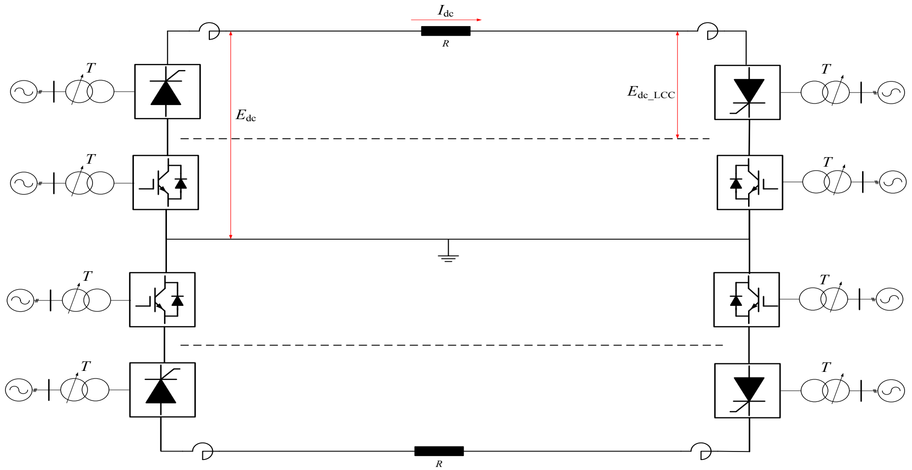
damping characteristics

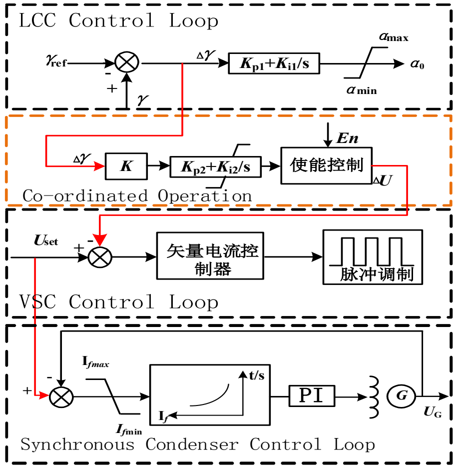
□ VSG could simulate the characteristics of synchronous generator, where the active power control is given based on synchronous generator rotor motion equation, the reactive power control is given based on excitation control.

□ VSG can provide active power frequency response control and damping characteristics .

3.1 Technical trends

❑ VSC-LCC Hybrid HVDC Technology





- ❑ VSC-LCC hybrid HVDC transmission may have some advantages, which will be used in different scenarios. The topology design of hybrid HVDC system should take the renewable energy generation characteristics, economy and reliability need into consideration.

- ❑ More researches on VSC-LCC HVDC will be focusing:
  - ✓ The design of system topology
  - ✓ the coordinated control strategy
  - ✓ Protection and control during system fault

3.2 Conclusions

- The high renewable energy penetration brings more challenges to power grid, the Chinese power system starts to experience **a reduction of system inertia,** frequency regulation and voltage regulation capability, and new oscillation happened frequently.
- The knowledges and roles of the RE in power grid are changing, **grid forming function** of RE as well as the power damping capability should be developed for improving grid voltage and frequency, **grid requirements to RE** need be continuously updated.
- More research activities are undergoing now in RE grid integration, for example digital-analog **hybrid simulation platform (HIL)** and modeling, VSG (grid-forming), LCC-VSC hybrid HVDC transmission technology, etc. **More technical exchanges and cooperation** will bring benefit.

Thanks！

Chief Engineer, renewable energy research center, CEPRI
Secretary, IEC SC 8A – Grid Integration of RE Generation

chiyn@epri.sgcc.com.cn   010-82813186