华北电力大学
NORTH CHINA ELECTRIC POWER UNIVERSITY

Wind Farm Technologies

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Outlines

1. NCEPU
2. Renewable Energy School
3. Wind Farm Technologies

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About NCEPU

华北电力大学
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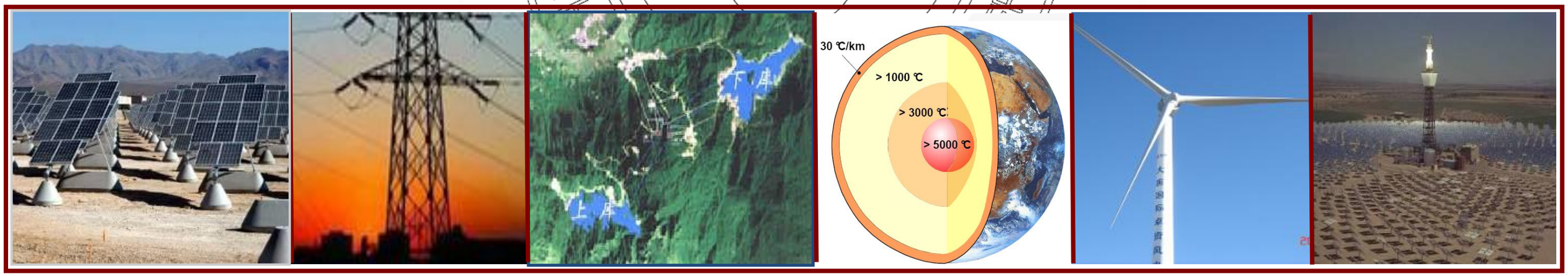
School of Renewable Energy

1. Overviews
2. Education
3. Research



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School of Renewable Energy of NCEPU

1. Overviews
2. Education
3. Research
4. Wind power research

1. Overview

- **Mission: To provide excellent education and high-level research on RE science and technology for China and the World, mainly on the 4 renewable energies: Solar, Wind, Hydro, and Biomass**
- **1st RE school in China (since 2007) , 1st undergraduate program on Wind Energy and Power Engineering in China (since 2006)**
- **Currently there are 88 academic staff, 1, 272 Undergraduate students, 304 Mater students, 37 PhD candidates**
- **Degrees awarded last 5 years: 1, 223 Bachelors, 206 Maters, 44 PhDs**
- **Research funding during last 5 years: 220 Million RMB, 55% from the government, 45 % from the industry**

2. Education

■ Undergraduate Majors

- ◆ New Energy Science and Engineering (National Characteristic Specialty) , with 3 Minors: Wind Energy, Solar Energy, Bio Energy.
- ◆ Materials and Device for New Energy
- ◆ Water Resources and Hydropower Engineering
- ◆ Hydrology and Water Resources Engineering

■ Master’s Programs

- ◆ Clean and Renewable Energy
- ◆ Water resources hydropower engineering
- ◆ Hydrology and Water Resources Engineering

■ PhD Program

- ◆ Clean and Renewable Energy

3. Research

■ Key Laboratory and Platform

- ◆ **State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources**
- ◆ **State Engineering Laboratory of Biomass Power and Equipments**
- ◆ **Beijing Key Laboratory of Novel Thin Film Solar Cells**
- ◆ **Beijing Key Laboratory of Energy Security and Clean Utilization**

Total Investment : 30 Million RMB; Total area : 2500m^2 ;
Large-scale experimental facilities and equipment: more than 50 sets

3. Research

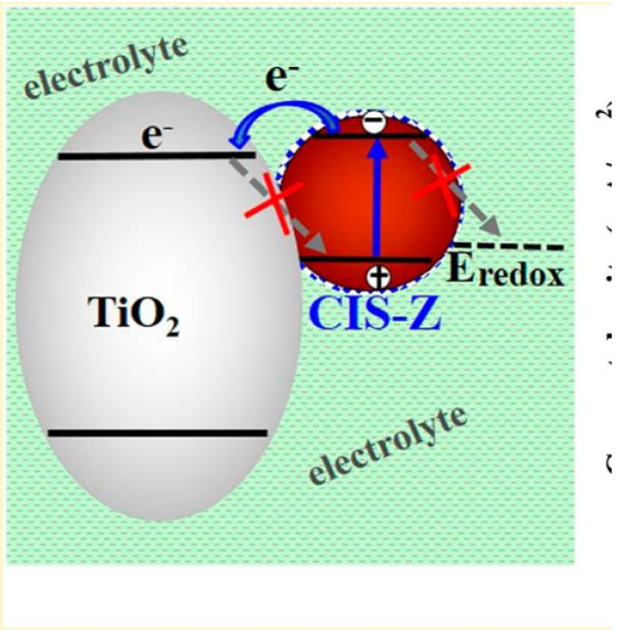
■ Research centers

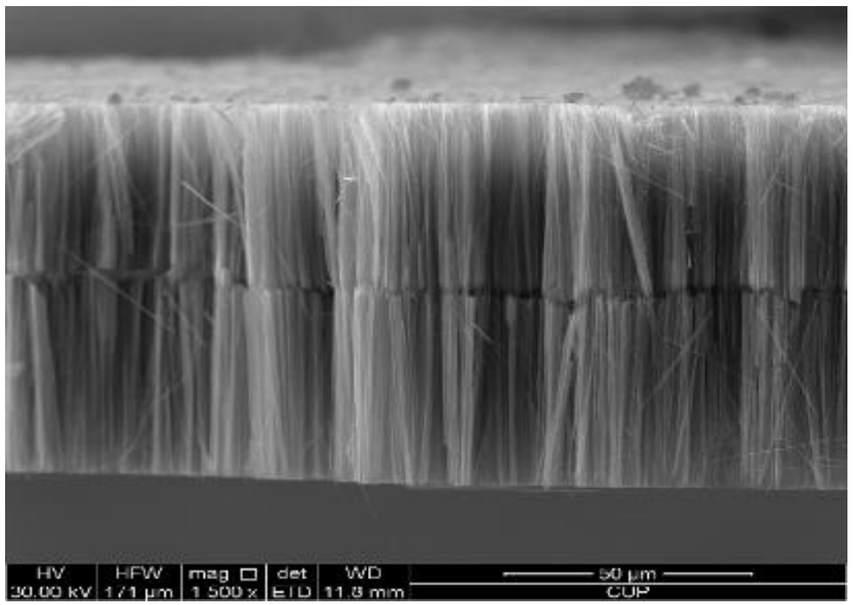
1. **Wind Power Research Center**
2. **Hydroelectric Energy & Engineering Research Center**
3. **Center for Solar Energy and Engineering**
4. **Center for New Energy Materials and Photoelectric Technology,**
5. **Biomass Energy Research Centre**
6. **New Energy Resources and Urban Environment Research Centre**
7. **Hydropower Resettlement Research Center**

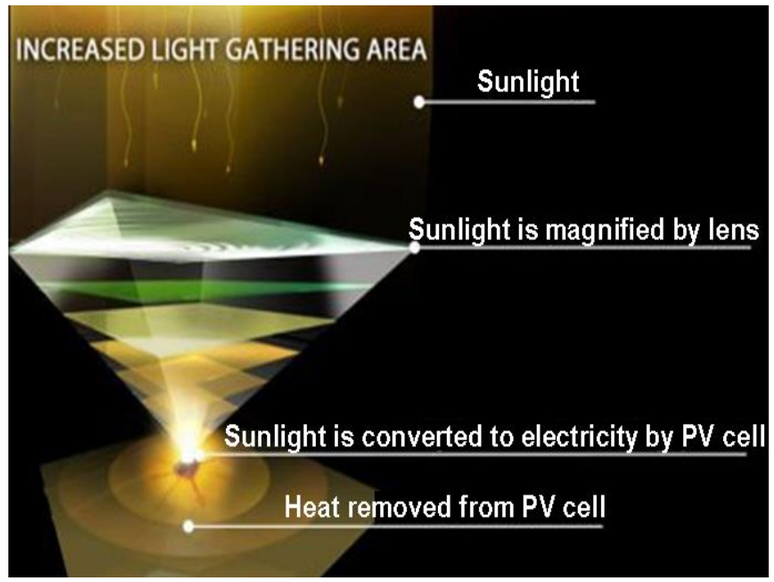
3. Research

☐ Solar Energy

- **Mechanism, theory and simulation of the photoelectric conversion process in solar cells.**
- **Solar cell materials and devices.**
- **Efficient and reliable photovoltaic operation technology.**
- **Concentration and tracking technology of Photovoltaic System.**



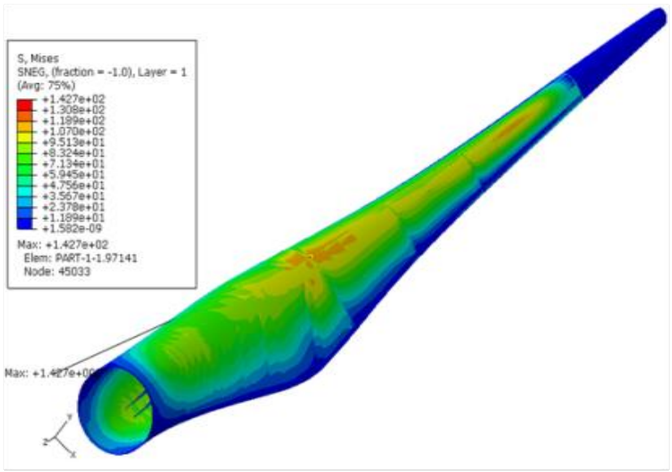


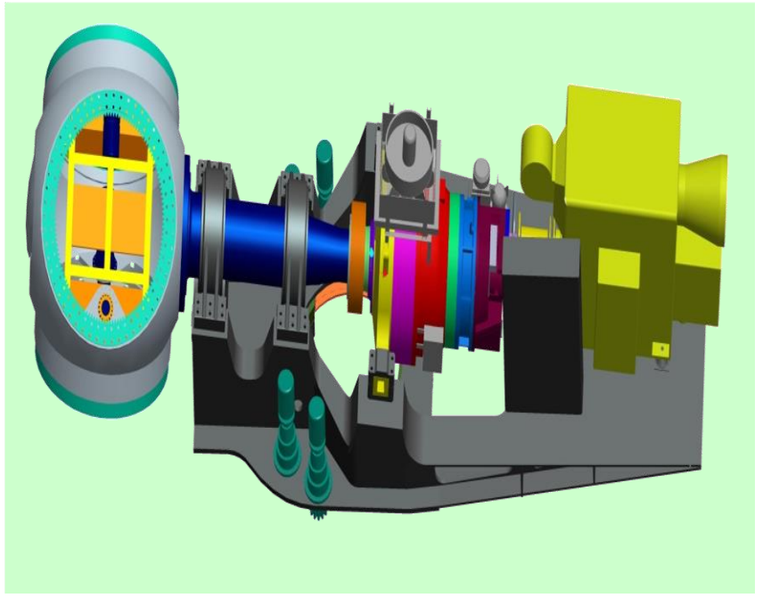


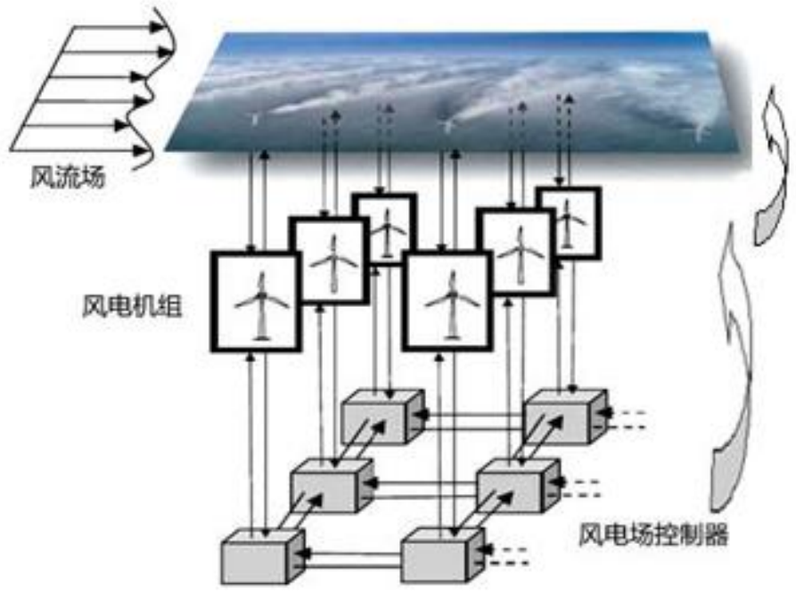
3. Research

Wind Power

- **Wind Turbine Generation System**
- **Wind Farm technologies**







3. Research

☐ Biomass Energy

- **Combustion, pyrolysis and gasification of biomass**
- **Technology and equipment for biomass power generation**
- **Anticorrosive materials for equipment of biomass power generation**
- **Theory and technology for solid waste treatment and utilization**

3. Research

☐ Hydro power and hydrology resources

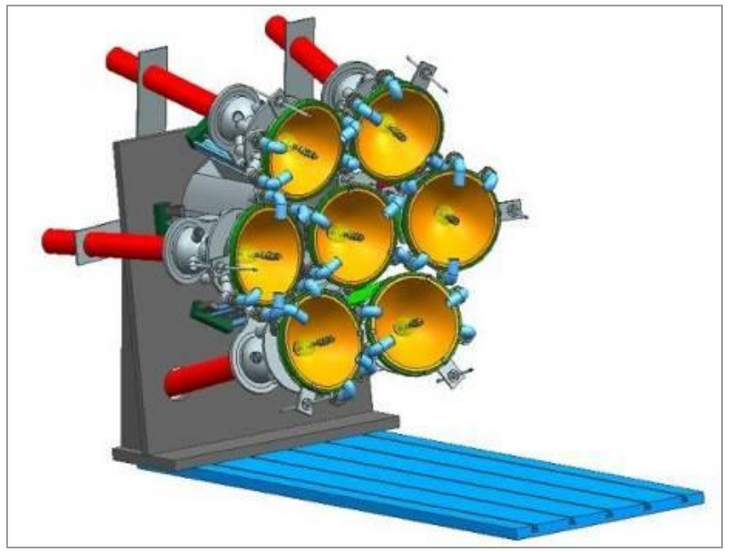
- **Hydrology and hydrological cycle**
- **Water resources planning and management system**
- **Hydro power economy**
- **Hydraulics and River Dynamics**

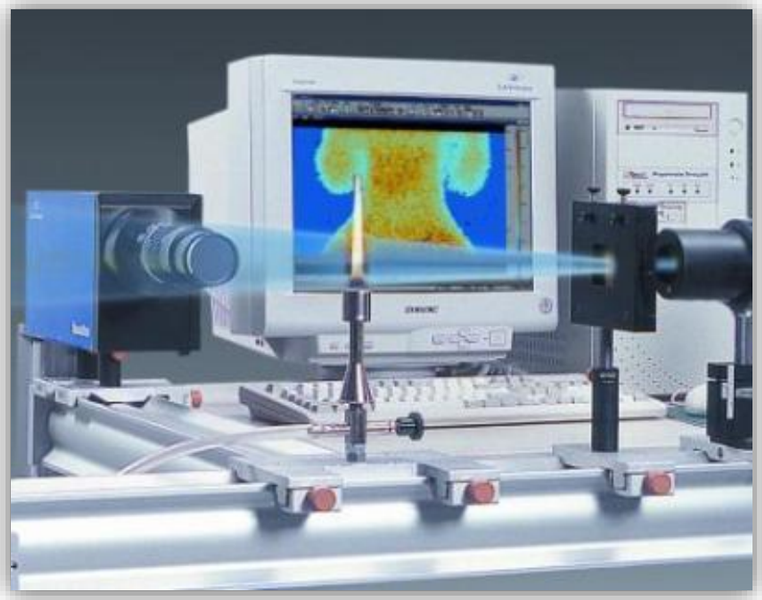
Large wind tunnel

Program of World Bank grants (CRESP).

- **interchangeable 2 test sections**
- **total length: 151.2m**
- **contraction ratio is 6.25**
- **the highest wind speed is 62m/s**

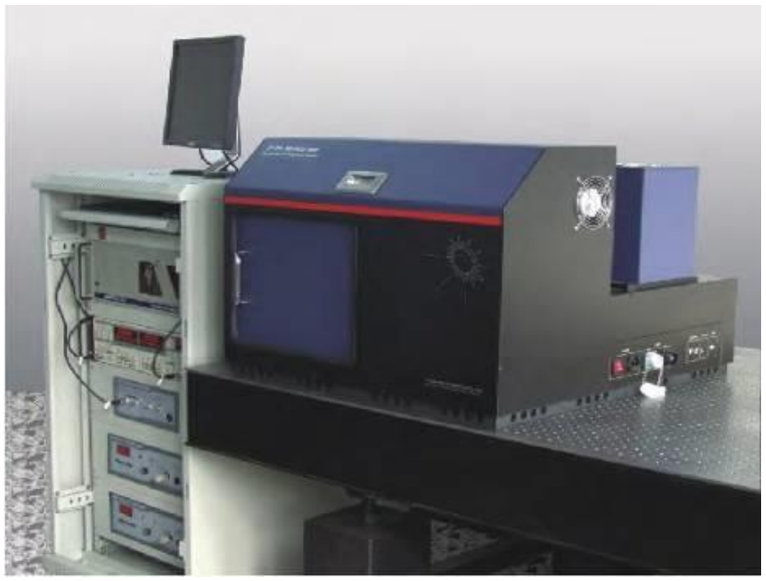
Solar simulation, preparation and test systems





PLIF平面激光诱导荧光火焰燃烧检测系统
Planar laser-induced fluorescence flame detection system

50kW太阳能模拟器 Solar simulator



光伏测量系统QE/IPCE
PV measurement system

等离子增强化学气相沉积系统
Plasma enhanced chemical vapor deposition system

Apparatus and platform for biomass

热重红外联用分析 **TG-FTIR Analyzer**

生物质气化试验平台
Experimental Platform for Biomass Gasification

多能互补沼气发酵中试装置
Pilot biogas plant heated by multi energy complementary

Wind Farm Technologies

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Wind Farm Technologies

Definition : the technologies of wind farms for its' whole lifecycle, including the technologies for the plan, design, construction, operation & maintenance, retrofitting, and dismantle.

Objective: (1)High safety and reliability of the wind farms; (2)Lower the coast for wind power (LCOE); (3)Increase the income;(4)Enhance the competency in the electricity market.

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Research on Wind Farm Technologies at NCEPU

Target: Minimize the costs in the full life-span of wind power generation

Wind Farm Design

- ✓Wind resource measurement and assessment
- ✓Wind farm macro-siting
- ✓Wind farm micro-siting
- ✓Wake modelling in wind farm

Wind Farm Operation and Maintenance

- ✓Wind turbines fault diagnosis
- ✓Health management for wind farm equipment
- ✓Optimal operation in wind farm

Operation of power system with high share of wind power

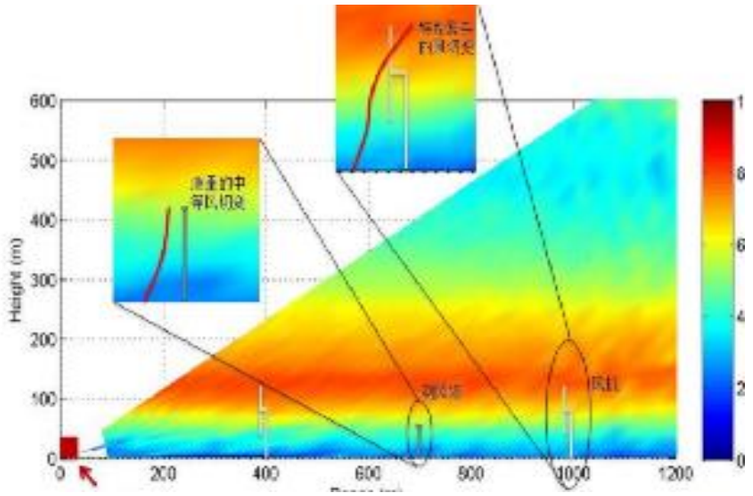
- ✓Wind power prediction technology
- ✓Wind power generation process characteristics and optimization control
- ✓Optimal operation of power system

Wind farm design: Wind resource measurement and assessment

One of the key technologies to the successful investment of a wind farm

Wind resources measurement

- **Wind measurement using LIDAR**
- **Measuring wakes in a wind farm**



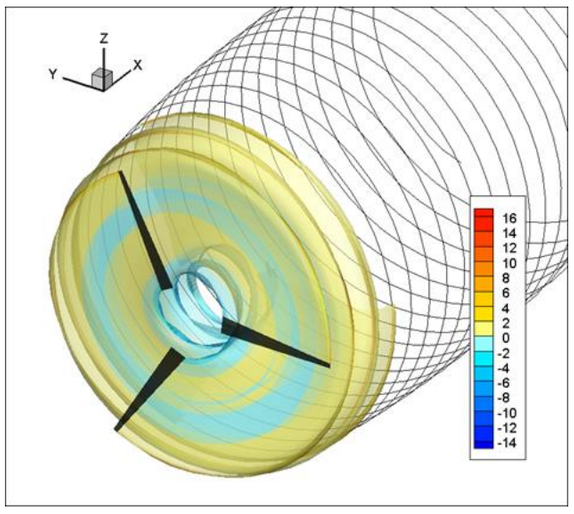
Wind resources assessment

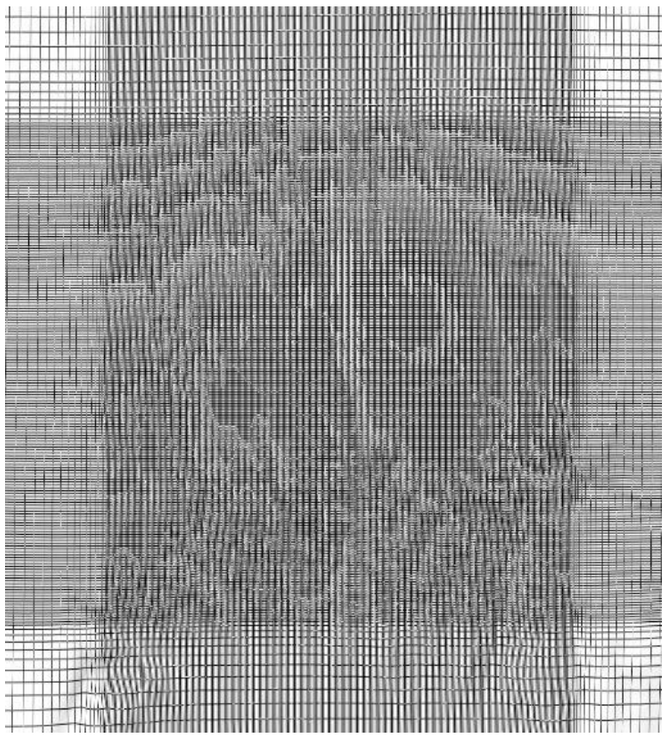
- **Wind periodicity analysis**
- **Wind fluctuation process clustering**
- **Wind resource assessment considering atmospheric stability**

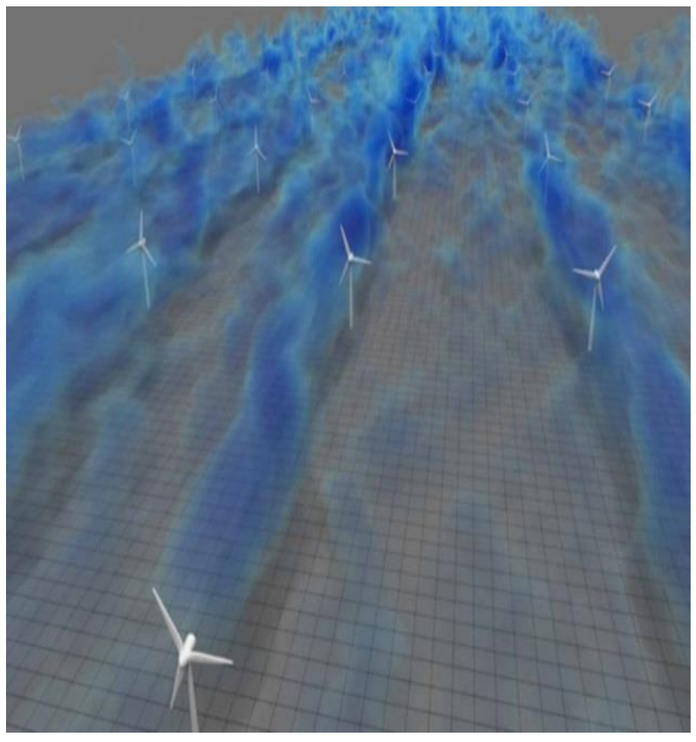
Wind farm design: Macro siting and micro siting for wind farms

Micro-siting Technology based on CFD simulation

- Wake effects modelling
- Layout of wind turbines
- High accuracy of annual energy(AEP)
- High efficiency of calculation







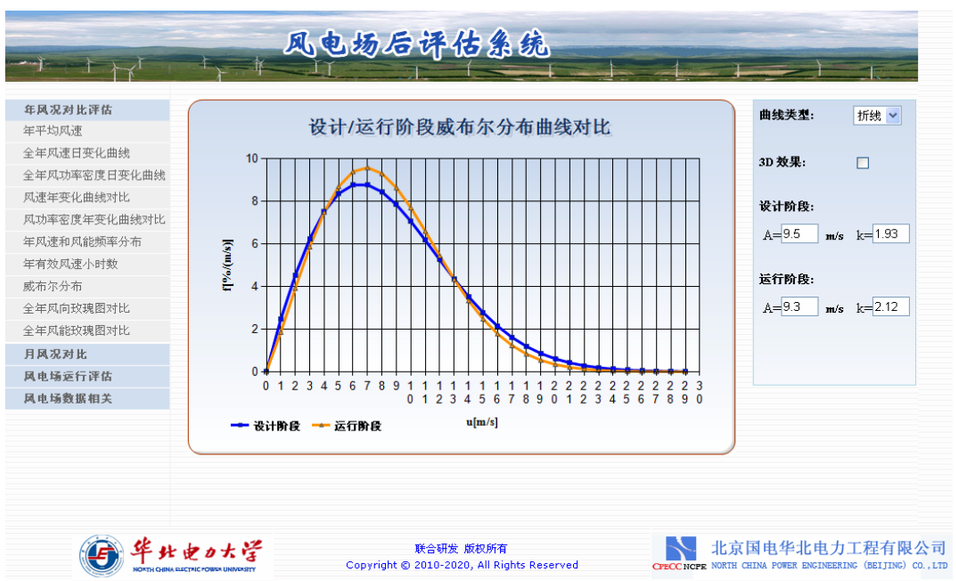
Wind farm design： optimization

Wind farm optimal design

- Wind farm design optimization through Post-evaluation
- Optimal design of electrical collection system in a wind farm

Wind turbine selection technology

- Matching the wind turbine and wind resource
- Considering the cost in the whole wind turbine lifetime
- Convenient in calculation and manipulation
- High wind energy production and low failure rate

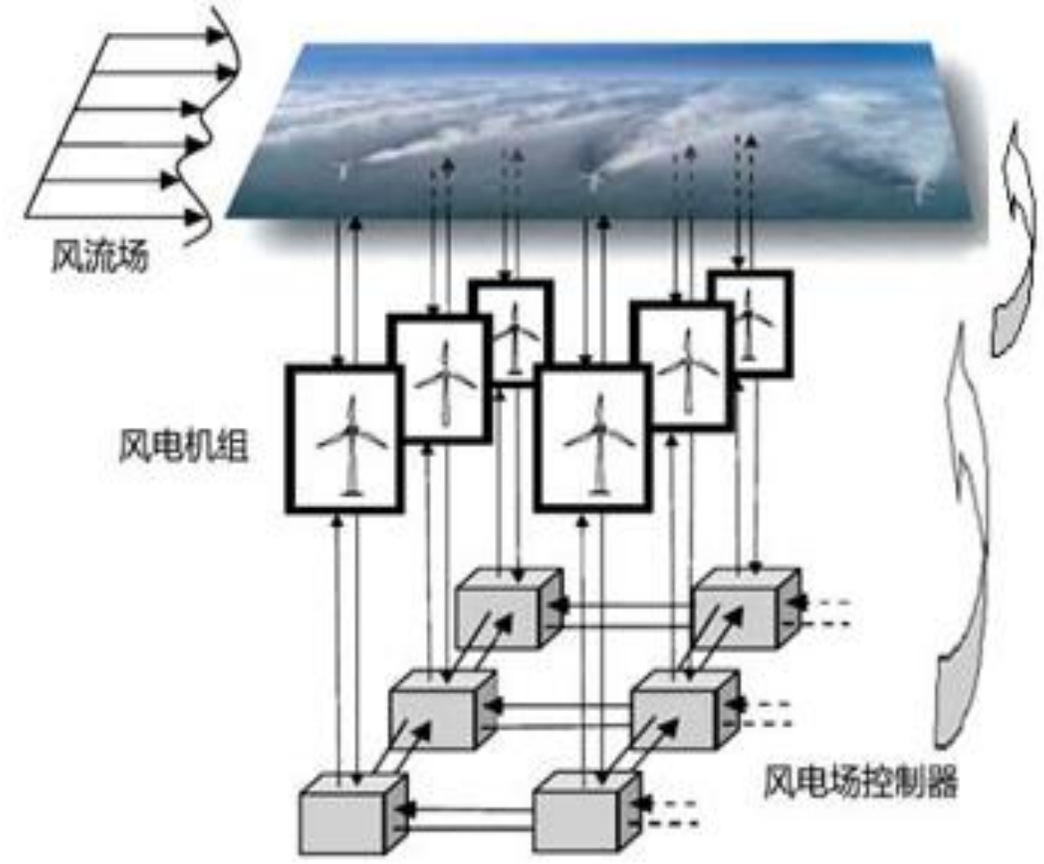


Wind farm operation optimization

Goals: Increase AEP and decrease cost

- To increase the power generation
- To extend the life span of wind turbines
- To optimize the power flow in wind farm

- Wake losses
- Mechanical damage
- Electrical loss



The whole wind farm output increased by 6.8% after the optimizing in the test case.

Wind farm maintenance

Condition monitoring and fault diagnosis

Off-line model building

Signal processing → Feature detection → Model training

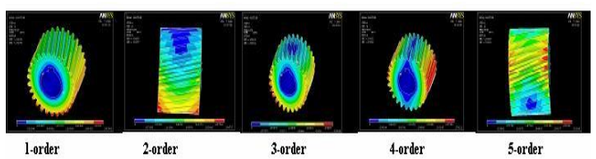
Online failure diagnosis

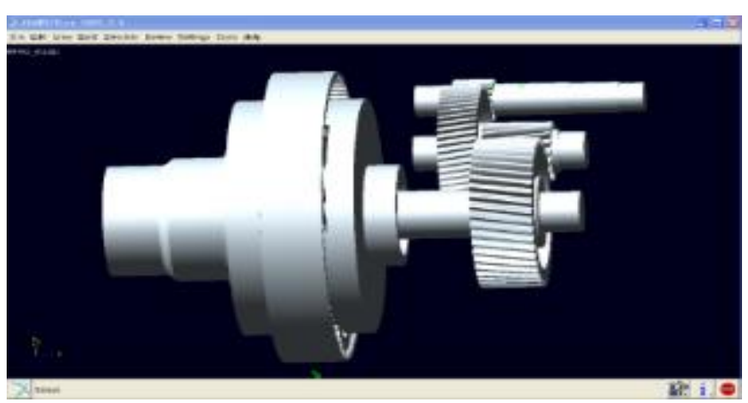
Real-time failure diagnosis → Feature detection → Pattern recognition model

Classification

→ Failure diagnosis

Physical modeling + big data analysis





Wind farm healthy management

Preventive maintenance

- Scheduled maintenance
- Condition Based Maintenance

- Data pre-processing method for condition monitoring of WTGS
- Fault modeling for key component, to study the fault mechanism and dynamic features, to assess the health state, to evaluate the residual life, and to locating the fault, etc.
- Fault pre-diagnosis and alarm
- Wind farm healthy index

Wind power prediction and its uncertainty analysis

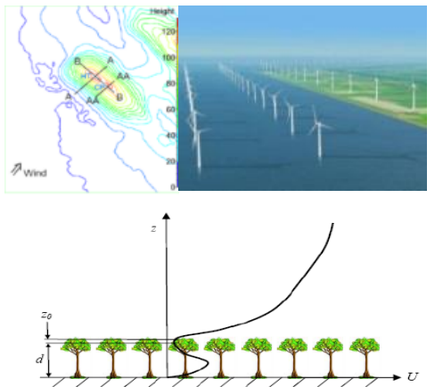
- **Reliable wind power prediction lays solid foundation to the optimal operation and decision-making in power system with high share of renewable energy.**

Functions

- ❑ Short-term prediction
- ❑ Ultra short-term prediction
- ❑ Uncertainty analysis of prediction results
- ❑ Automatic remote update of the model

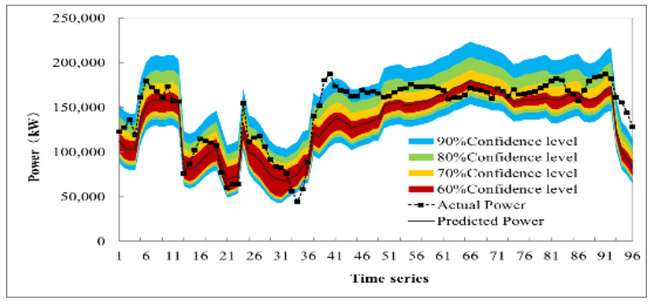
Adaptabilities

- ❑ Different topographies (plain or hilly ground)
- ❑ Offshore wind farm



Uncertainty analysis

- ❑ 3 uncertainty analysis methods
- ❑ Power interval or probabilistic distribution under given confidence level



Mathematical theory

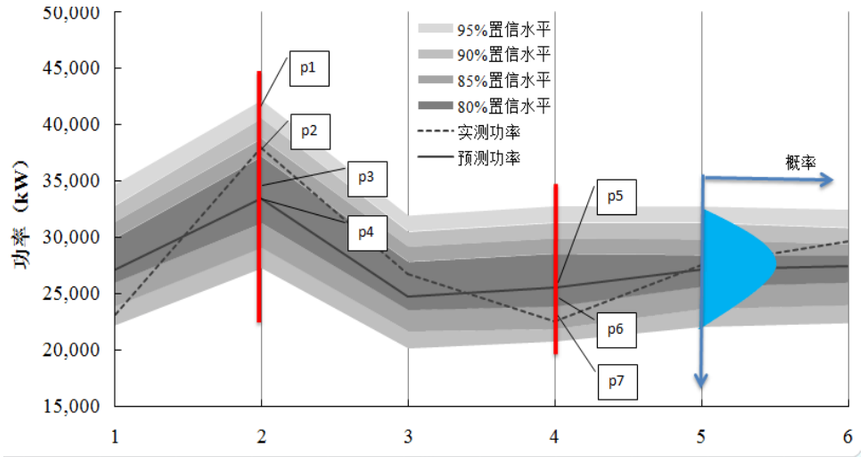
- ❑ 4 Short-term prediction statistic models
- ❑ 7 super short-term prediction statistic models
- ❑ Physic model based on CFD flow field pre-calculation

Development of a wind power prediction system

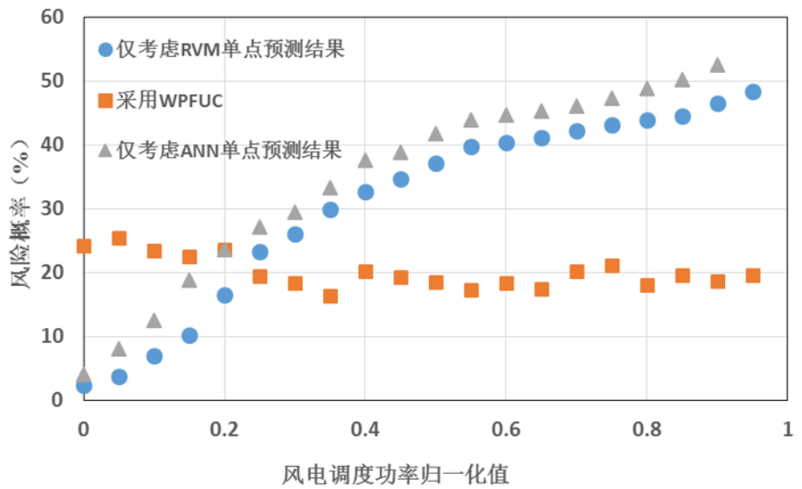
- **Funded by National 863 program**
- **Funded by National Natural Science Foundation: Physical method study for wind power prediction based on CFD numerical simulation database**
- **6 patents, 23 publications, and 1 software copyright**
- **Graduated 21 Master students and 9 PhD students**

Power system operation with large penetration of wind power

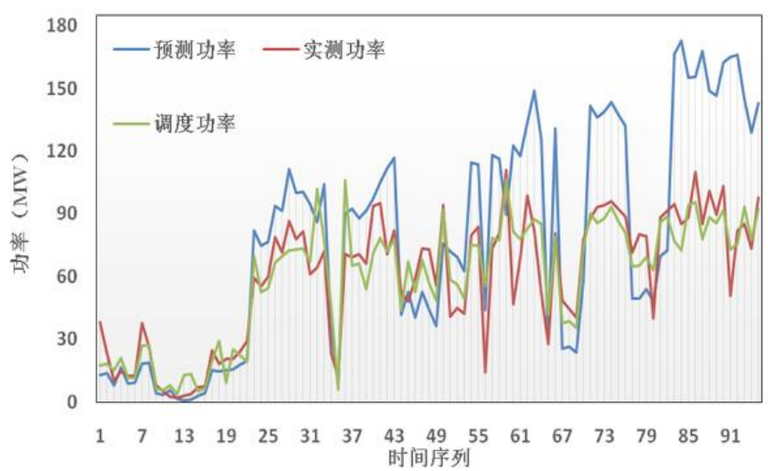
- **Cost Modelling for Balancing Wind Power Forecasting Uncertainty**
  - Wind power uncertainty incremental cost (WPUIC)
  - Wind power uncertainty dispatch cost (WPUDC) – a quadratic function
- **Economic dispatch based on probabilistic forecasting of wind power**



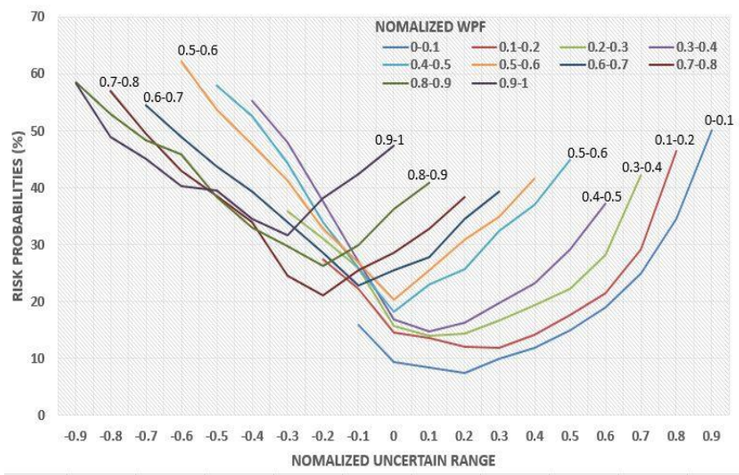
Schematic diagram for uncertainty-based decision making



Risk probabilities for wind power dispatching



Curves of actual, predicted and scheduled wind power



Risk with respect to normalized uncertain wind power ranges

Thank you !