Wind Farm Technologies

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Outlines

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

NORTH CHINA ELECTRIC POWER UNIVERSITY
School of Renewable Energy

1. Overviews
2. Education
3. Research

2016年11月20日
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**
  - 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: 2500m²; Large-scale experimental facilities and equipment: more than 50 sets
### 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

50kW 太阳能模拟器 Solar simulator

光伏测量系统 QE/IPCE PV measurement system

PLIF 平面激光诱导荧光火焰燃烧检测系统

等离子增强化学气相沉积系统

Planar laser-induced fluorescence flame detection system

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

Pilot biogas plant heated by multi energy complementary
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 cost for wind power (LCOE); (3) Increase the income; (4) Enhance the competency in the electricity market.
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
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

Wind farm healthy management

- Preventive maintenance
- Scheduled maintenance
- Condition Based Maintenance

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

- 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
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

- 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

Development of a wind power prediction system
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!