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# **Study on Wind Power Grid-Integration China Experience (中国风电并网研究)**

**China EPRI, ZHU Lingzhi  
2013-09 Beijing, China**

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■ Models and Tools for Grid integration study  
风电并网研究的模型与工具

■ Problem and Suggested Improvement  
风电并网研究的不足与改进

# 1.1 Developing Mode of Wind Power 风电开发模式



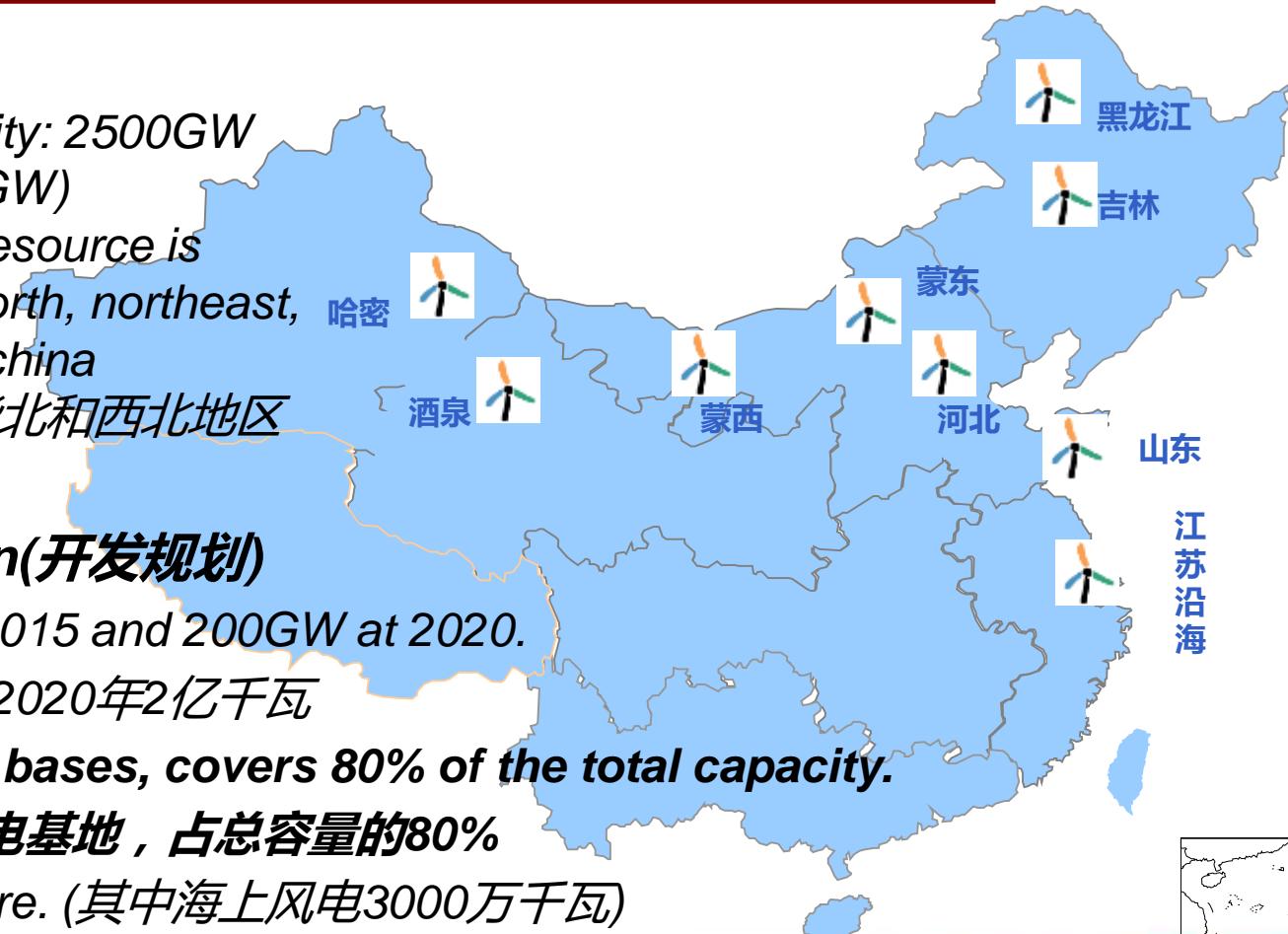
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## ● Bulk Wind Power Base (千万千瓦级风电基地)

### Resource(资源)

- Exploitable capacity: 2500GW  
(技术可开发量25GW)
- 80% of the wind resource is concentrated in north, northeast, and northwest of china

80%位于东北、华北和西北地区



### Development Plan(发展规划)

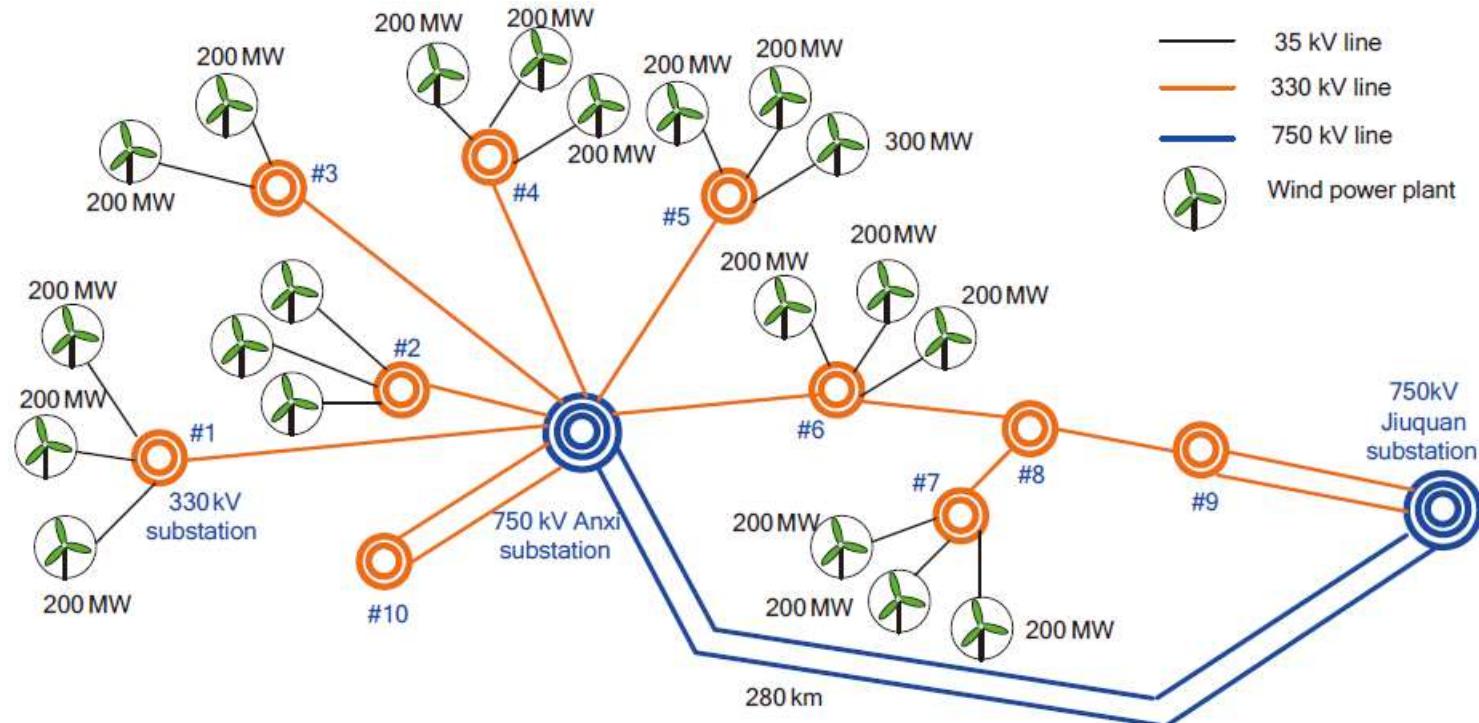
- Up to 100GW at 2015 and 200GW at 2020.  
2015年1亿千瓦，2020年2亿千瓦
- Nine 10GW wind bases, covers 80% of the total capacity.  
9个千万千瓦级风电基地，占总容量的80%
- 30GW are off-shore. (其中海上风电3000万千瓦)

# 1.1 Developing Mode of Wind Power 风电开发模式



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## ● Bulk Wind Power Base (千万千瓦级风电基地)



- *Several wind farm connected collection substation, Wind power are transferred through UHV or EHV.*

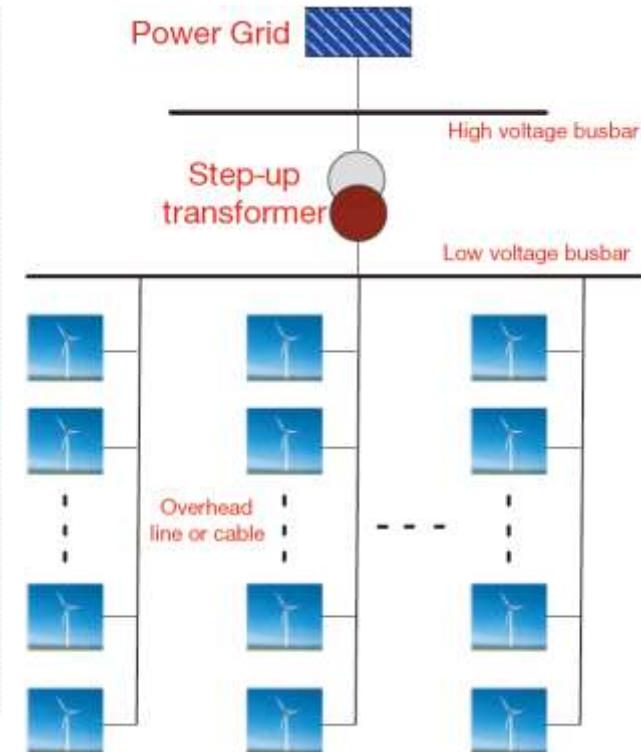
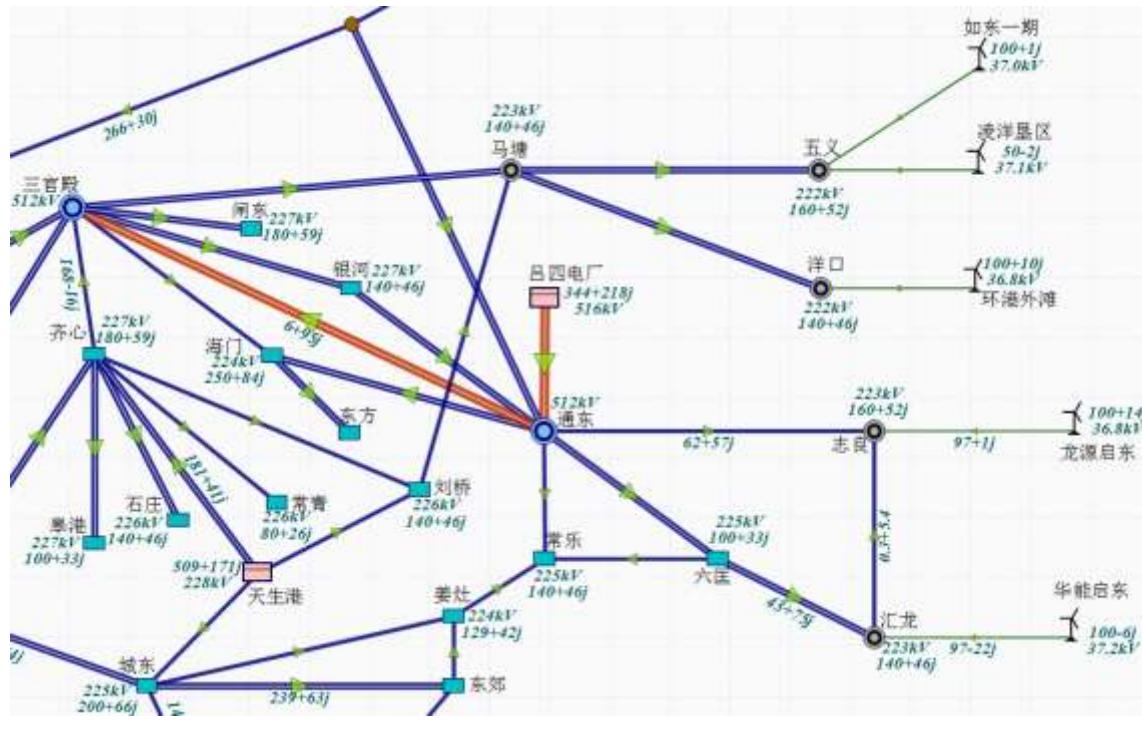
多个风电场接入汇集站，通过超高压或特高压输电通道送出

# 1.1 Developing Mode of Wind Power 风电开发模式



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## ● Large Scale Wind Farm (大规模风电场)



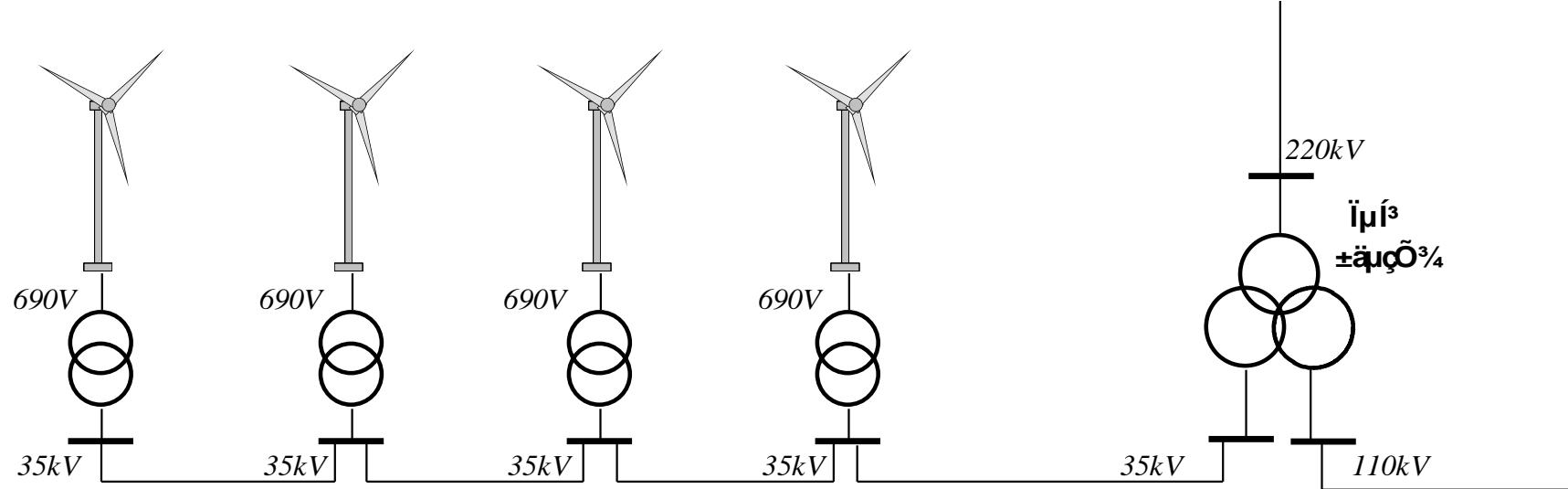
- Each wind farm 50-200MW (单个风电场装机50-200MW )
- Connected to the grid through 110-220kV line (通过110-220kV线路接入电网 )
- Electricity are consumed inside a province (电力一般在省内消纳 ).

# 1.1 Developing Mode of Wind Power 风电开发模式



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## ● Distributed Wind Farm (分散式风电)



- Connected to local substation through 10-35kV line, long distance power transfer is not necessary. (10-35kV接入，电力无需远距离传输)
- Total installation capacity is normally less than 20MW at single PCC. (单个接入点容量一般不超过20MW)
- Covers a relatively small part of wind power in china. (占比相对较少)

# 1.2 Wind Turbines in China

## 中国的风电机组

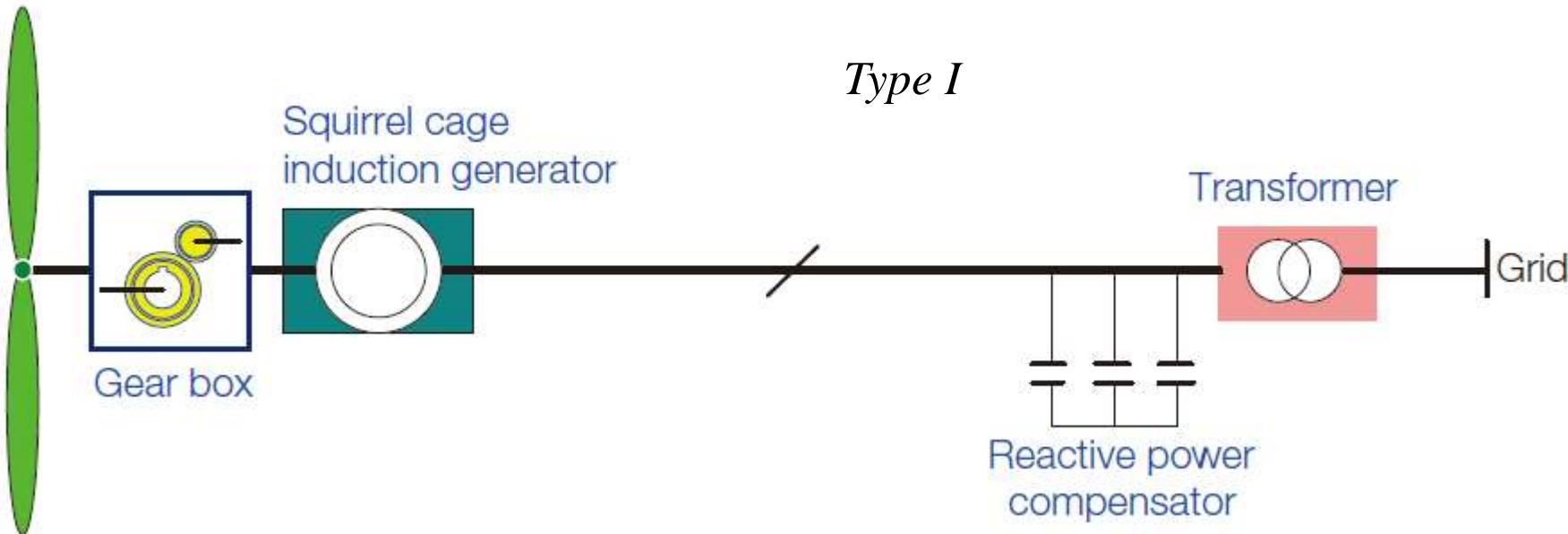


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### ● Three Types of Wind Turbine (三种主要的机组类型)

*Fixed Pitch Induction Wind Generator*

定桨距失速型异步感应风电机组



- *Early Type, rarely seen in new installed wind turbines, but still in operation.*  
(早期机型，已逐渐退出市场，但仍具有一部分存量)
- *Less than 1MW.* (单机容量1MW以下)

# 1.2 Wind Turbines in China

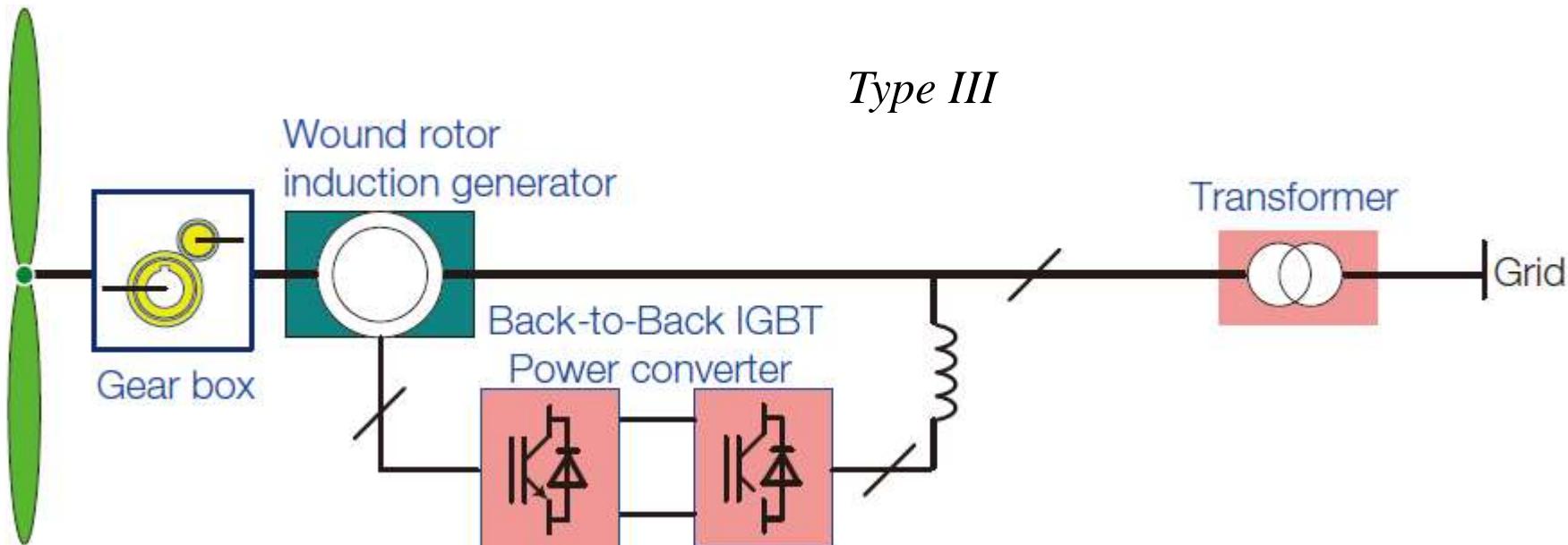
## 中国的风电机组



国家电网  
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### ● Three Types of Wind Turbine (三种主要的机组类型)

*Doubly Feed Asynchronous Induction Generator (DFIG/DFAg)*  
变桨距双馈异步感应风力发电机组



- Main Type, covers about 75% of new installed wind turbines.  
主流机型，占新装机型的75%左右
- 1.5MW and above. (单机容量1.5MW及以上).

# 1.2 Wind Turbines in China

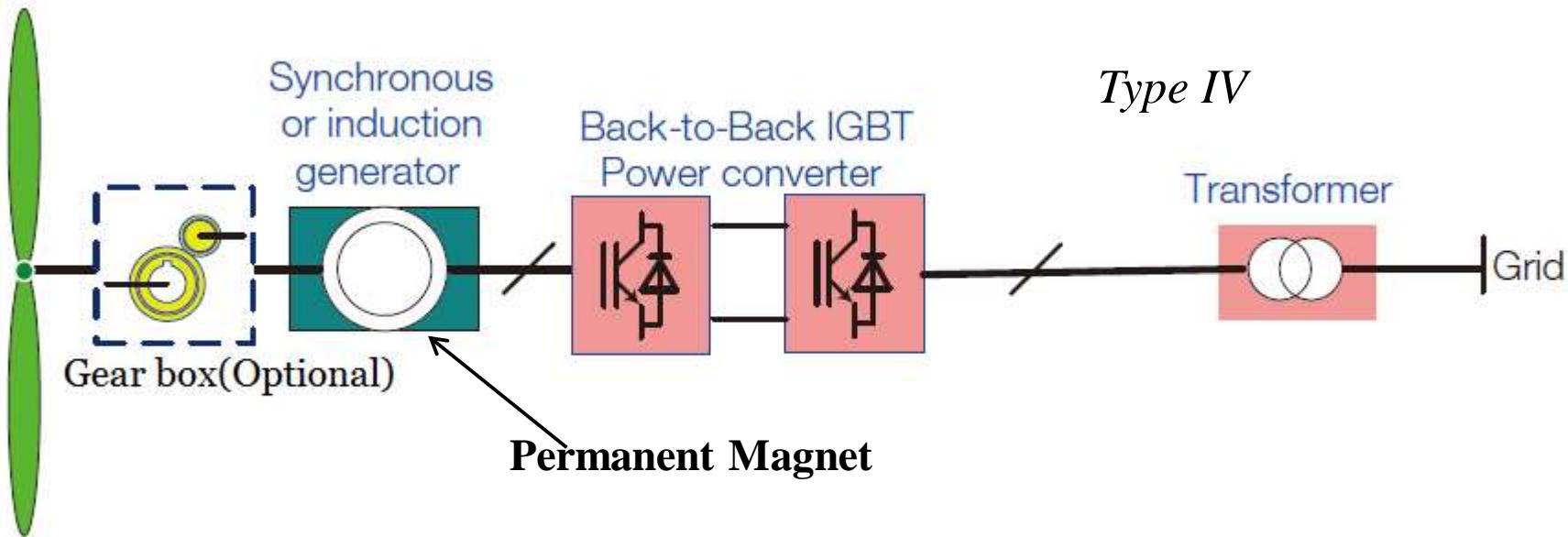
## 中国的风电机组



国家电网  
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### ● Three Types of Wind Turbine (三种主要的机组类型)

*Permanent Magnet Synchronous Generator(PMSG) with Full rated Converter*  
永磁直驱同步风电机组 (全功率变流器)



- Main Type, covers about 25% of new installed wind turbines.  
主流机型，占新装机型的25%左右
- 1.5MW and above. (单机容量1.5MW及以上).

# Content (目 录)



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## ■ Wind Power in China

中国风电情况

## ■ Study on Grid Integration of Wind Power

风电并网研究

## ■ Models and Tools for Grid integration study

风电并网研究的模型与工具

## ■ Problem and Suggested Improvement

风电并网研究的不足与改进

## 2.1 Two Types of Grid-integration Study 两种类型的并网研究



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- **Special Study on Wind Farm Grid Integration**  
**(风电场接入电力系统专题研究)**

- *Done while wind farm is planning*  
在风电场规划前期阶段进行
- *Help to Design the grid-integrated system of wind farm*  
指导风电场并网系统的设计

- **Analysis of Large Scale Wind Power Trip-off**  
**(风电大规模脱网事故分析)**

- *Analysis the procedure of wind power trip-off and find the reason.*  
分析风电大规模脱网事故发生的原因
- *Bring out suggestion to improve the stability of the grid with high penetration wind power*  
提出改进风电接入系统稳定性的措施

## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



### ● Contents (主要内容)

- *Analysis of Wind Resource* (风能资源分析)
- *Load Flow and Reactive Power Study* (潮流和无功问题研究)
- *Short Circuit Current Analysis* (短路电流分析)
- *Study on Transient Stability* (暂态稳定分析)
- *Study on Power Quality Problem* (电能质量问题分析)

## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



### ● Analysis of Wind Resource (风能资源分析)

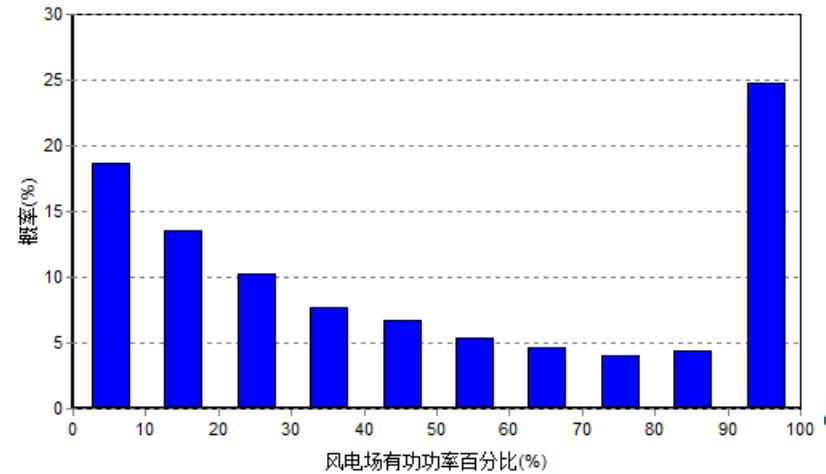
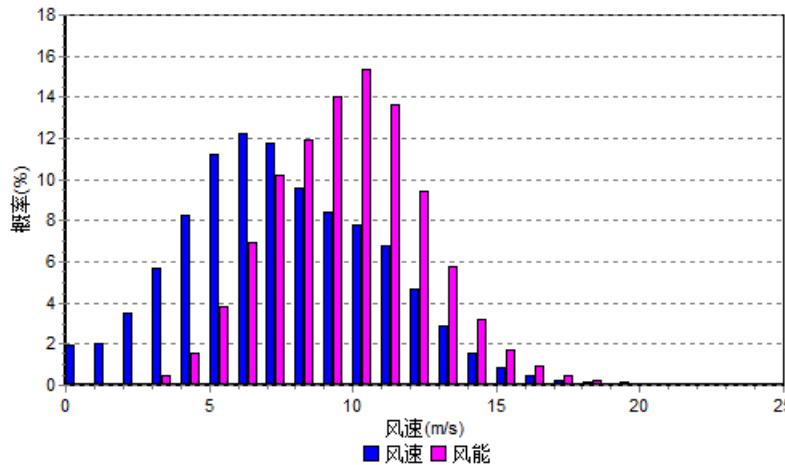
#### Goals(目标)

- Calculate the probability distribution of power output and power ramp of the wind farm according to measured wind resource data

根据实测风速数据，计算风电场出力及其变化的概率分布

- Analysis the relationship between local load and wind power output according to local load characteristic

根据电网的负荷数据，分析风电场出力与所在地区负荷相关性



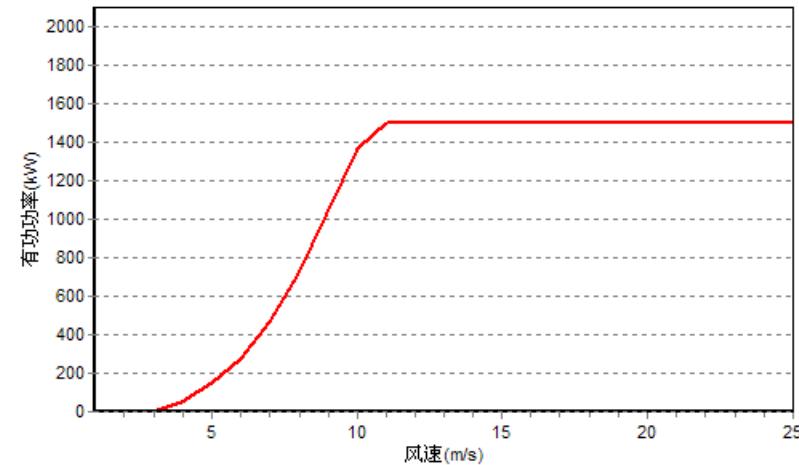
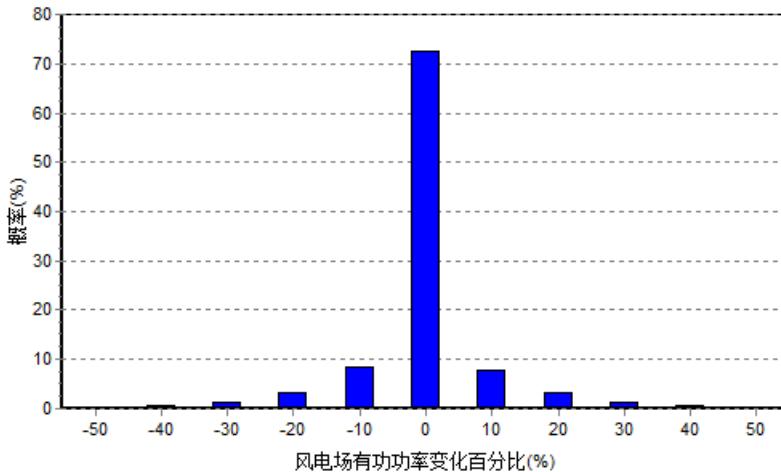
## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



### ● Analysis of Wind Resource (风能资源分析)

#### Data Requirement(数据需求)

- Measured wind resource data(more than 1 year) 风资源数据(至少一年)
- Data about the wind farm. 风电场建设数据
- Power curve of wind turbines to be installed(风电机组功率特性曲线)



## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



### ● Load Flow and Reactive Power Study (潮流无功研究)

#### Goals(目标)

- Evaluate the impact on system load flow and voltage level.  
评估风电场接入后对电网潮流分布、无功电压水平的影响。
- Give suggestions of voltage regulation and var compensation of the wind farm and grid. 给出风电场和系统的电压调整和无功补偿建议

#### Data Requirement

- Static grid data  
电网静态数据
- Typical system operation scenario  
典型系统运行方式

出力(%)	无功交换	
	风电场侧	110kV母线侧
0	-0.57	1.16
10	-0.66	1.06
20	-0.92	0.74
30	-1.35	0.21
40	-1.94	-0.54
50	-2.71	-1.48
60	-3.64	-2.63
70	-4.74	-4.00
80	-6.02	-5.60
90	-7.49	-7.42
100	-9.16	-9.49

## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



### ● Study on Short Circuit Current (短路电流计算)

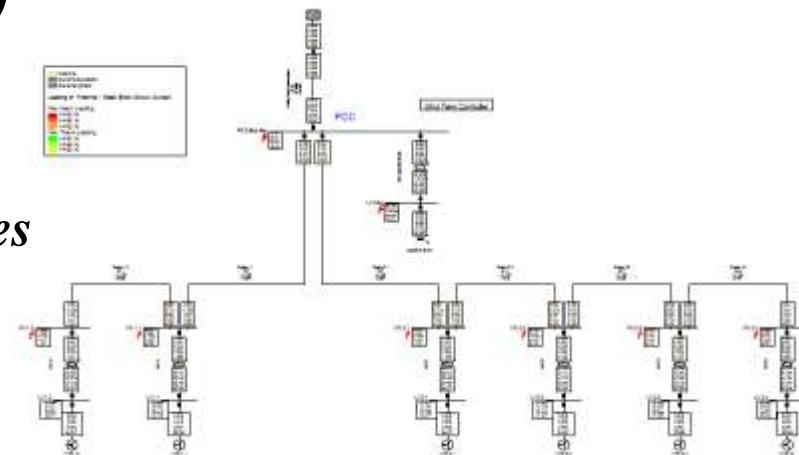
#### Goals(目标)

- Analysis short circuit current output of the wind farm and its impact on short circuit level of the local power system.*

计算风电场的短路电流输出特性，分析风电场接入后对所在区域电网短路电流水平的影响。

#### Data Requirement (数据需求)

- Static grid data*  
电网静态数据
- Short circuit character of wind turbines*  
风电机组短路电流特性
- Short circuit character of generators of the power system*  
系统发电机短路电流特性



## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



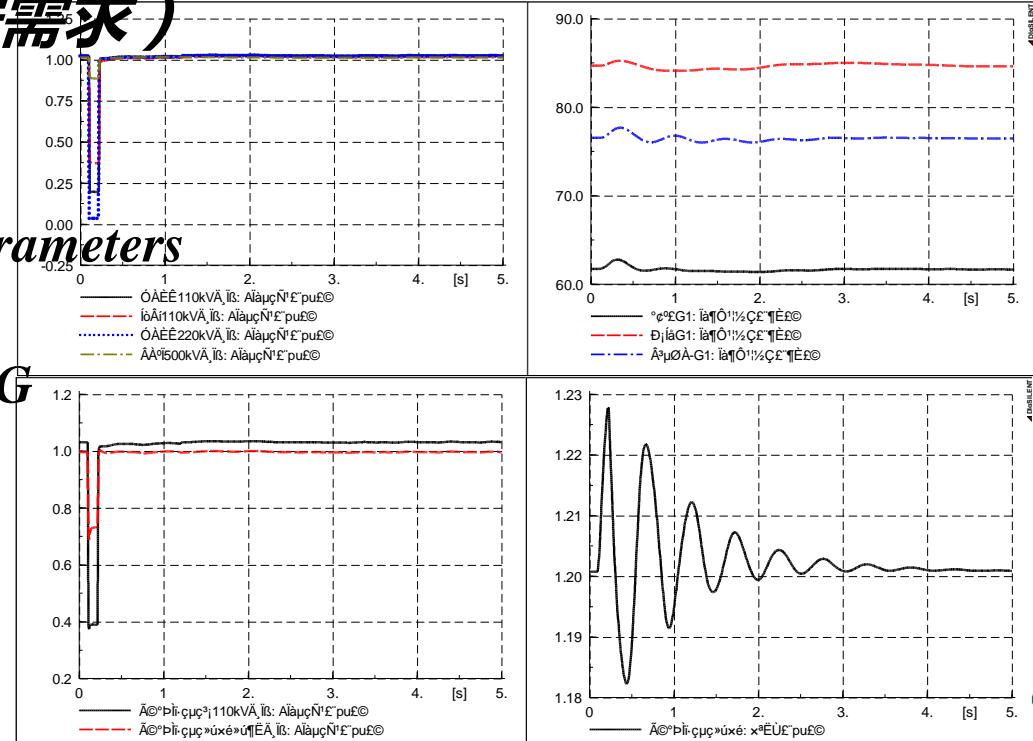
### ● Study on Transient Stability (暂态稳定性分析)

#### Goals(目标)

- Evaluate the impact to power system transient stability of the wind farm*  
评估风电场接入后对电网暂态稳定性的影响。

#### Data Requirement (数据需求)

- Static grid data*  
电网静态数据
- System dynamic model and parameters*  
系统动态模型和参数
- Models and parameters of WTG*  
风电机组模型和参数
- Typical fault type*  
典型故障方式



## 2.2 Special Study on Wind Farm Grid Integration 风电场接入电力系统专题研究



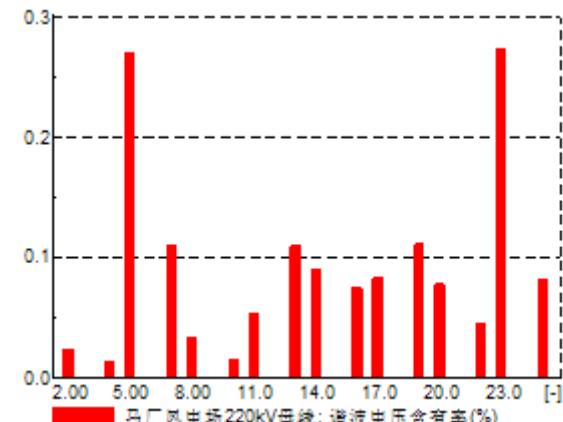
### ● Study on Harmonics (电能质量问题研究)

#### Goals(目标)

- Calculate the voltage harmonic distortion of PCC considering harmonic current injection from wind farm*  
考虑风电场并网产生的谐波电流注入后，计算风电场接入点的电压谐波畸变；

#### Data Requirement ( 数据需求 )

- Static grid data*  
电网静态数据
- Data of the collection system of the wind farm*  
风电场集电系统参数
- Harmonic test data of WTGs*  
风电机组谐波测试数据



## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



### ● Goals (目标)

- *Analysis the procedure of wind power trip-off.*  
分析风电大规模脱网事故发生的过程
- *Reappear the procedure by simulation and find the reason.*  
通过仿真再现事故发生的过程并分析导致事故的原因
- *Bring out suggestion to improve the stability of the grid with high penetration wind power*  
提出改进风电接入系统稳定性的措施

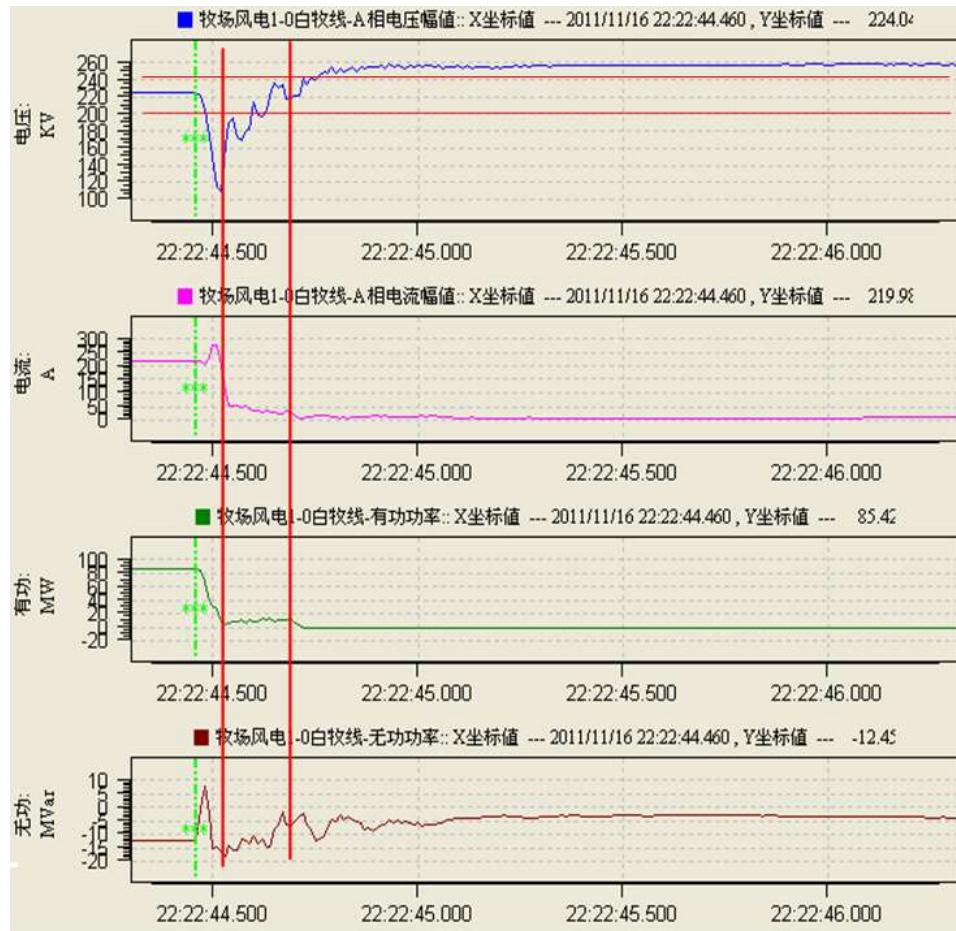
### ● Data requirement (数据需求)

- *System operation scenario before and after accident.*  
系统事故前后运行状态
- *Fault data from PMU and fault recorder*  
来自PMU或故障录波仪的故障数据
- *Model of WTGs especial LVRT character*  
风电机组模型，特别是LVRT特性

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



- *Record data of wind farm A from a trip off Accident  
(某事故中风电场A录波数据)*



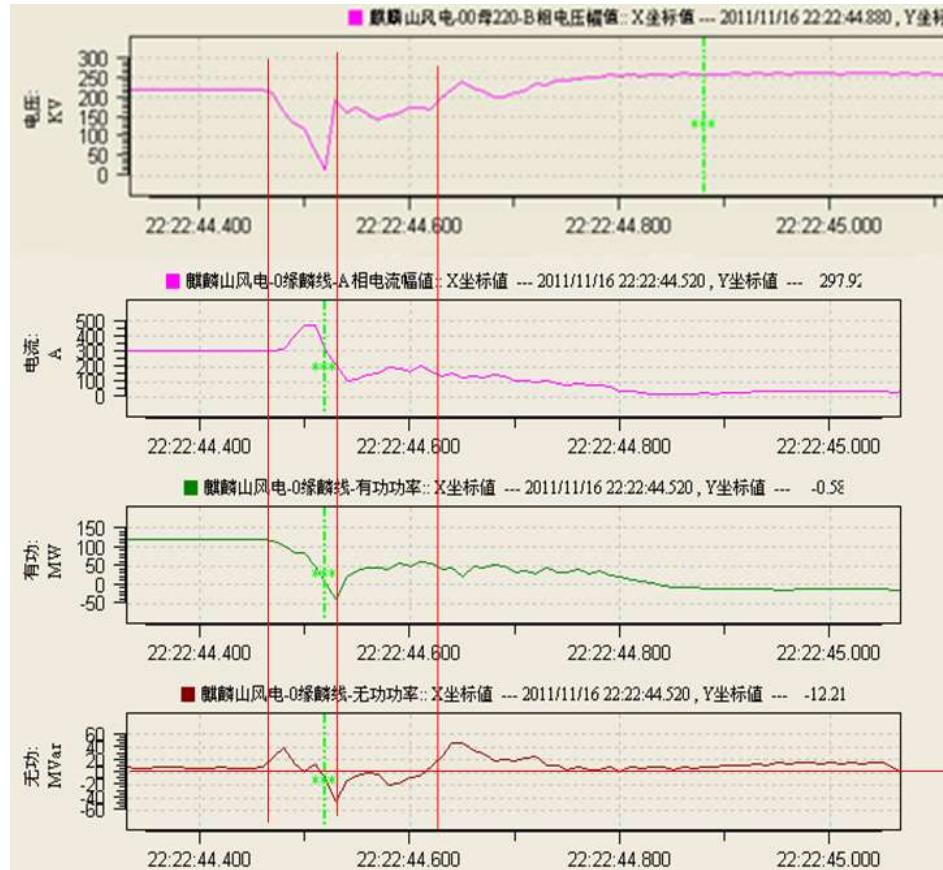
*The WTGs of wind farm A don't have the ability of FRT and trip off because of under voltage protection when fault occurs.*

**该风电场机组不具备故障穿越能力，故障发生时由于低压保护而脱网**

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



- *Record data of wind farm B from a trip off Accident  
(某事故中风电场B录波数据)*



*Some WTGs of wind farm B don't have the ability of LVRT and trip off because of under voltage protection when fault occurs.*

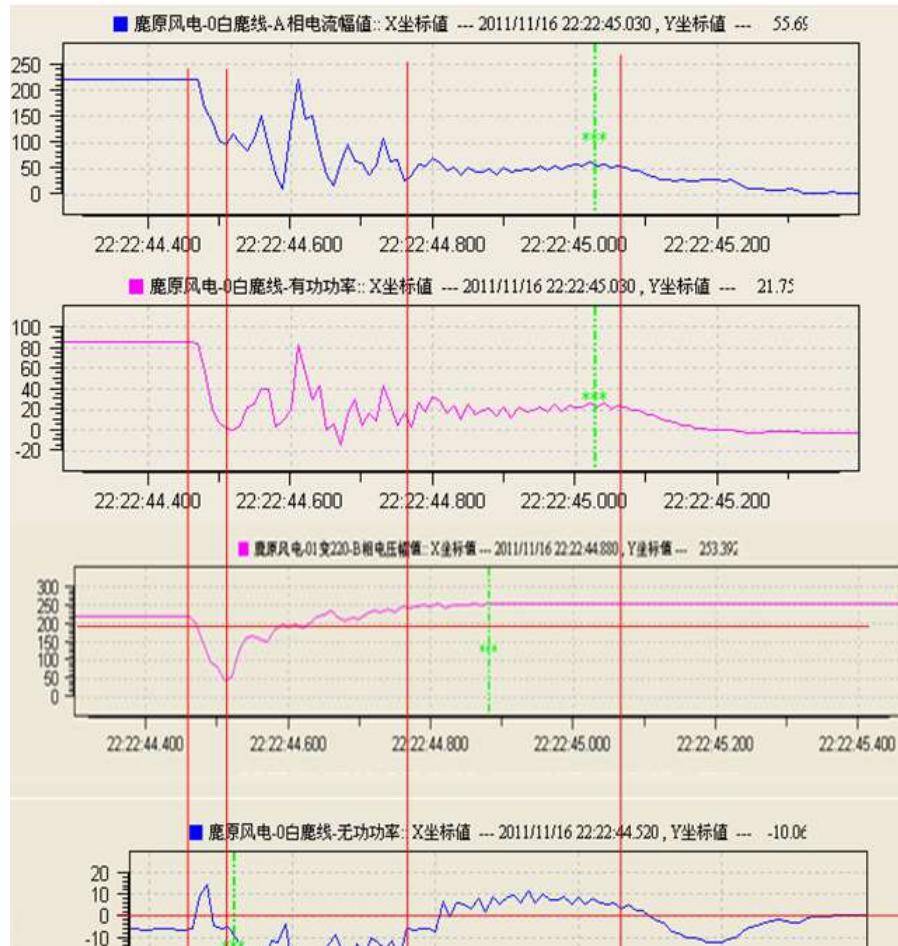
*Some WTGs have the ability of LVRT but trip off because of over voltage protection when fault cleared.*

**该风电场部分机组不具备故障穿越能力，故障发生时由于低压保护而脱网。部分机组具备低电压穿越能力，但在故障清除后由于高压保护而脱网**

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



- ***Record data of wind farm C from a trip off Accident***  
**(某事故中风电场C录波数据)**



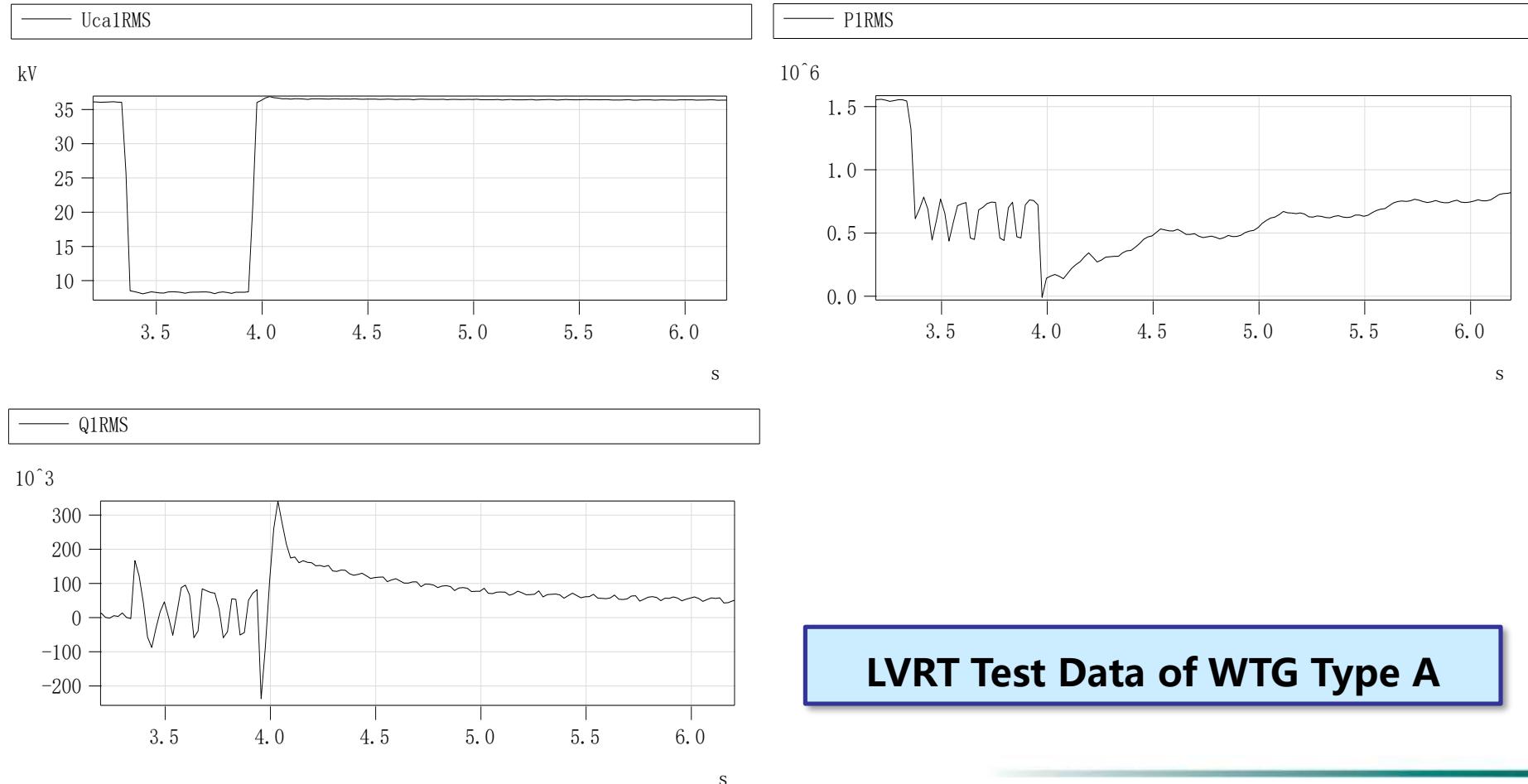
*The WTGs of wind farm C have the ability of LVRT and didn't trip off when fault occurs. But some WTGs trip off because of over voltage protection when fault cleared.*

**风电场C机组具备低电压穿越能力，故障发生时未脱网，但仍有部分机组在故障清除后由于高电压保护而脱网**

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



### ● LVRT Character of WTG(风电机组低电压穿越特性)

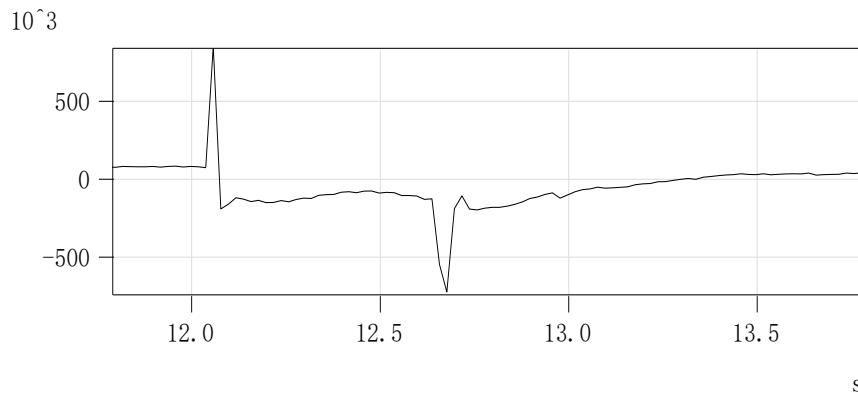
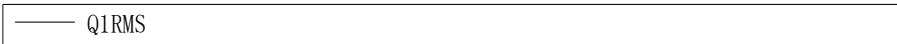
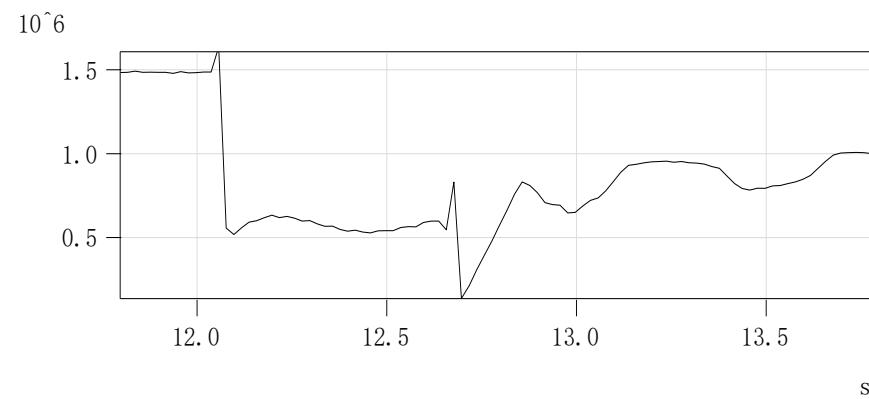
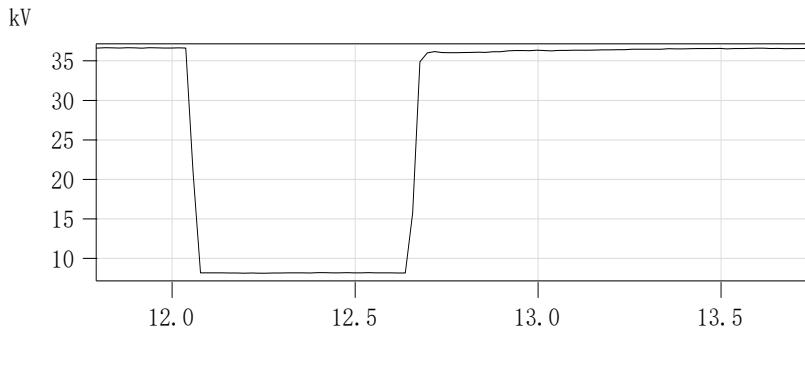


LVRT Test Data of WTG Type A

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



### ● LVRT Character of WTG(风电机组低电压穿越特性)

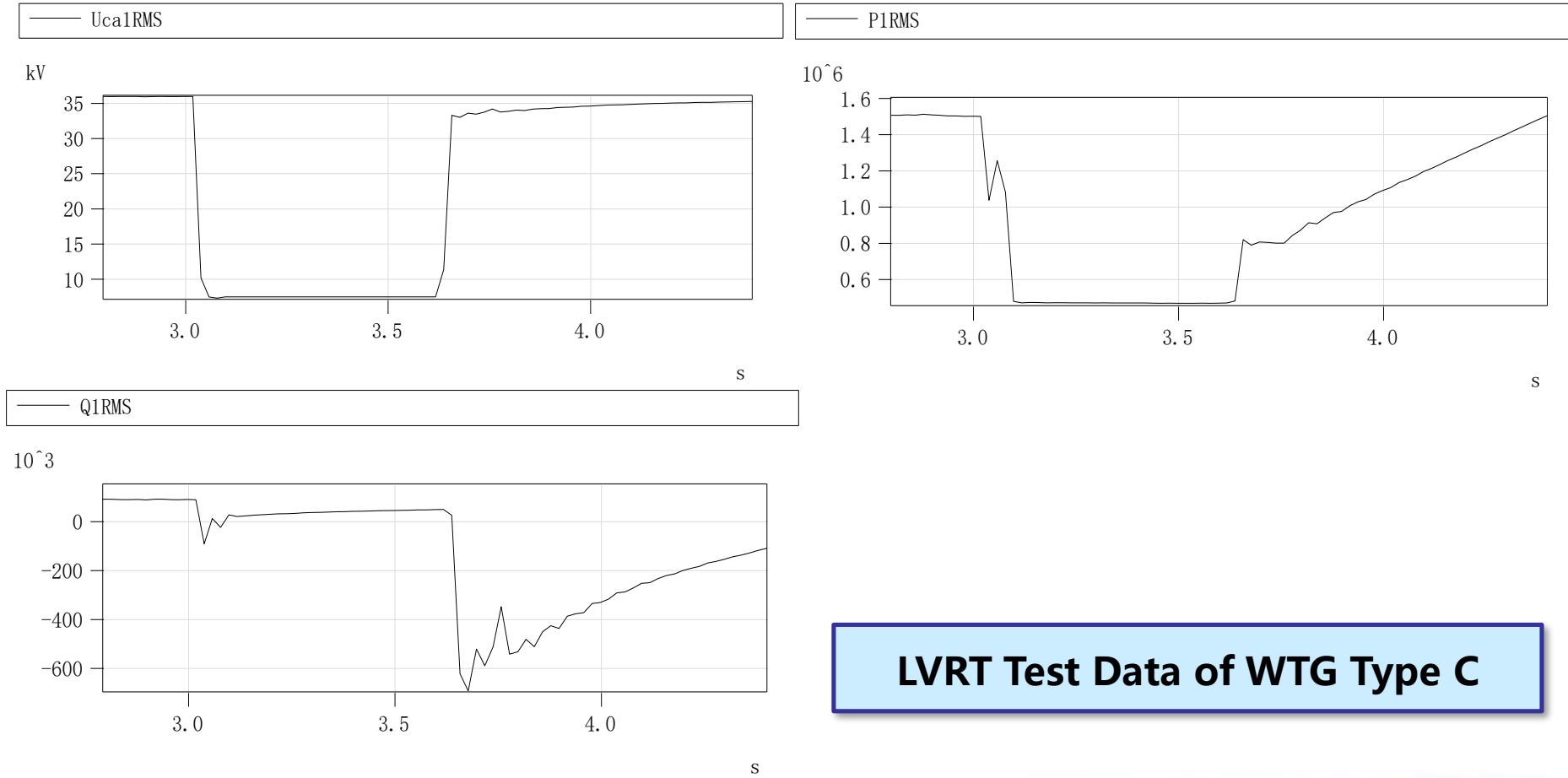


LVRT Test Data of WTG Type B

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



### ● LVRT Character of WTG(风电机组低电压穿越特性)

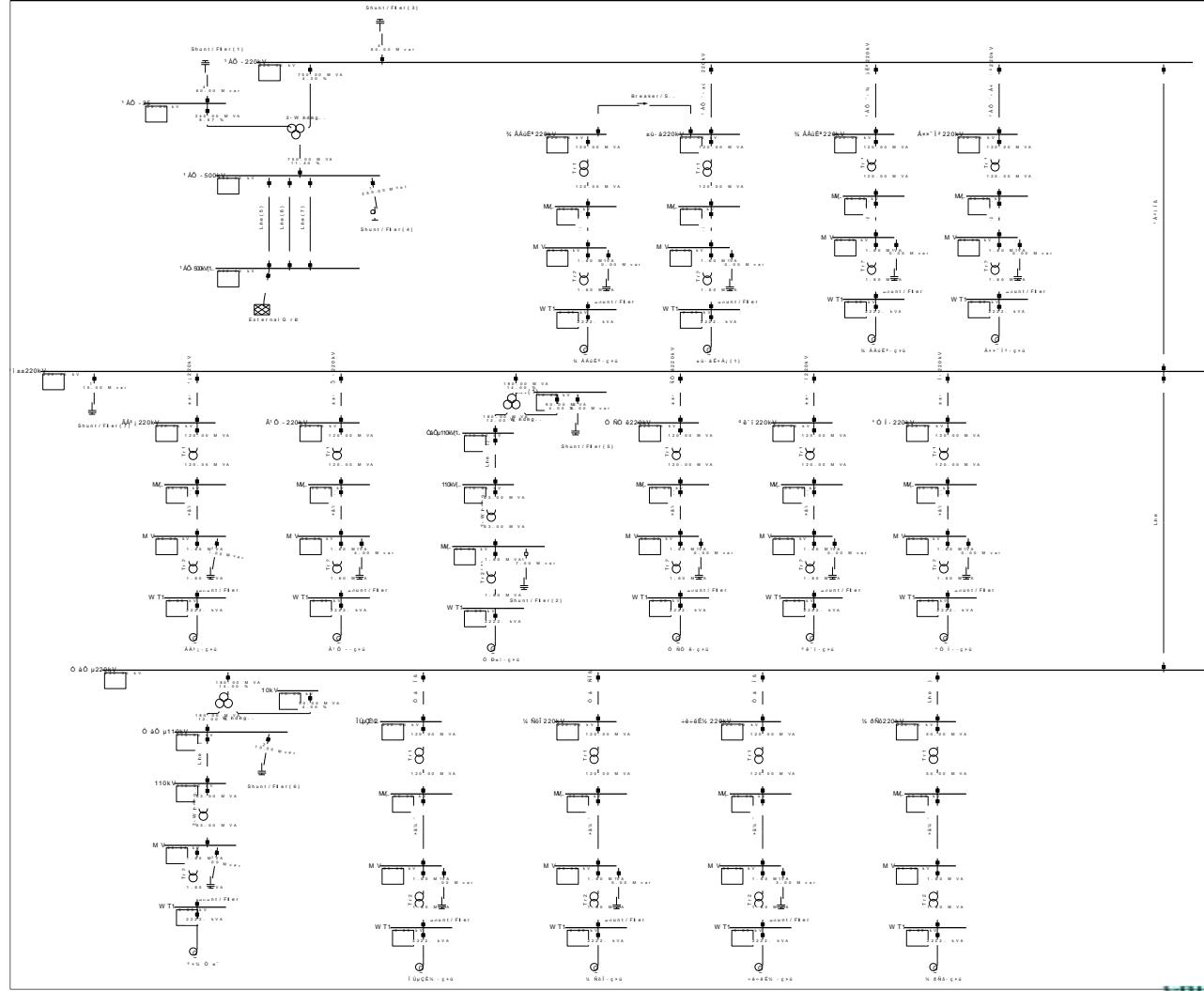


LVRT Test Data of WTG Type C

## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



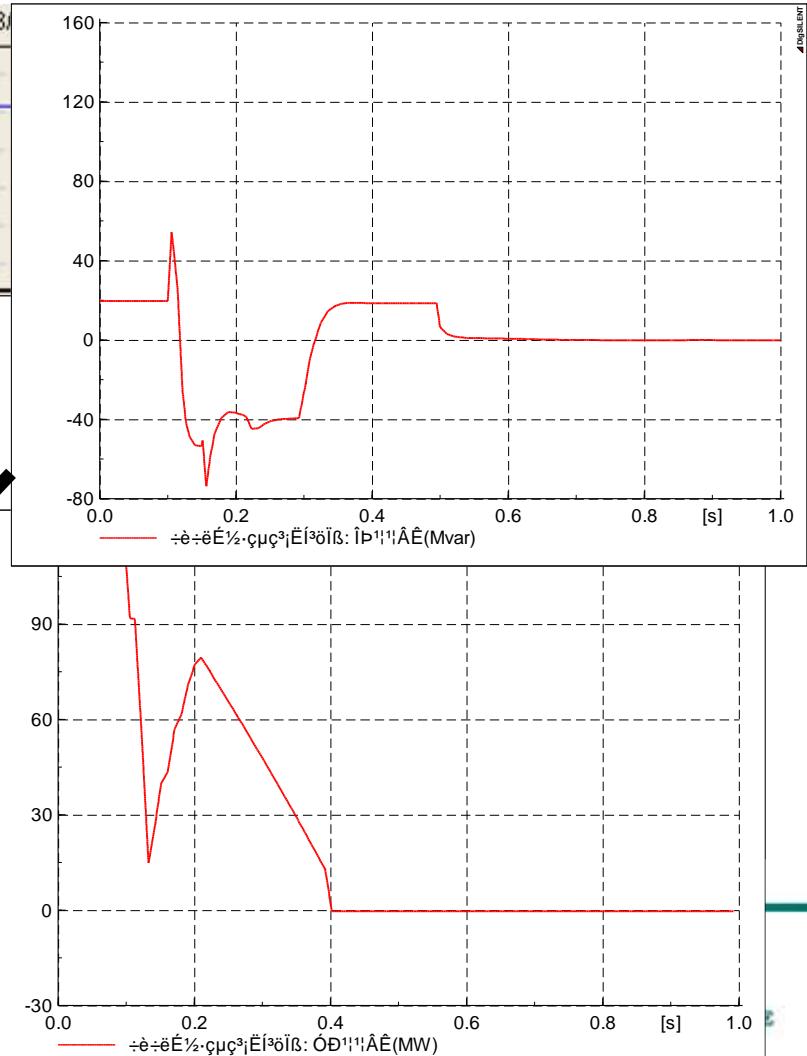
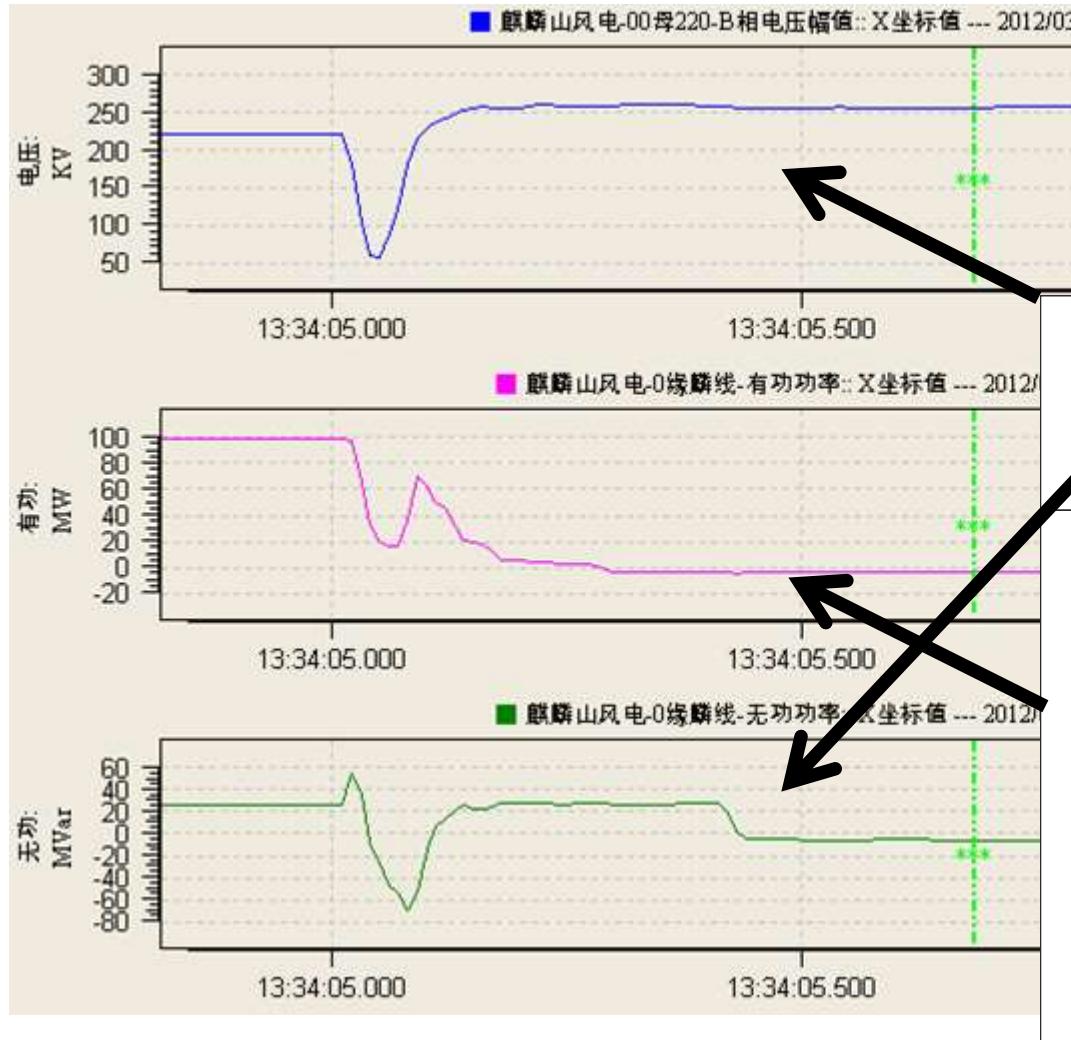
### ● *Simulation of the Accident(事故仿真)*



## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



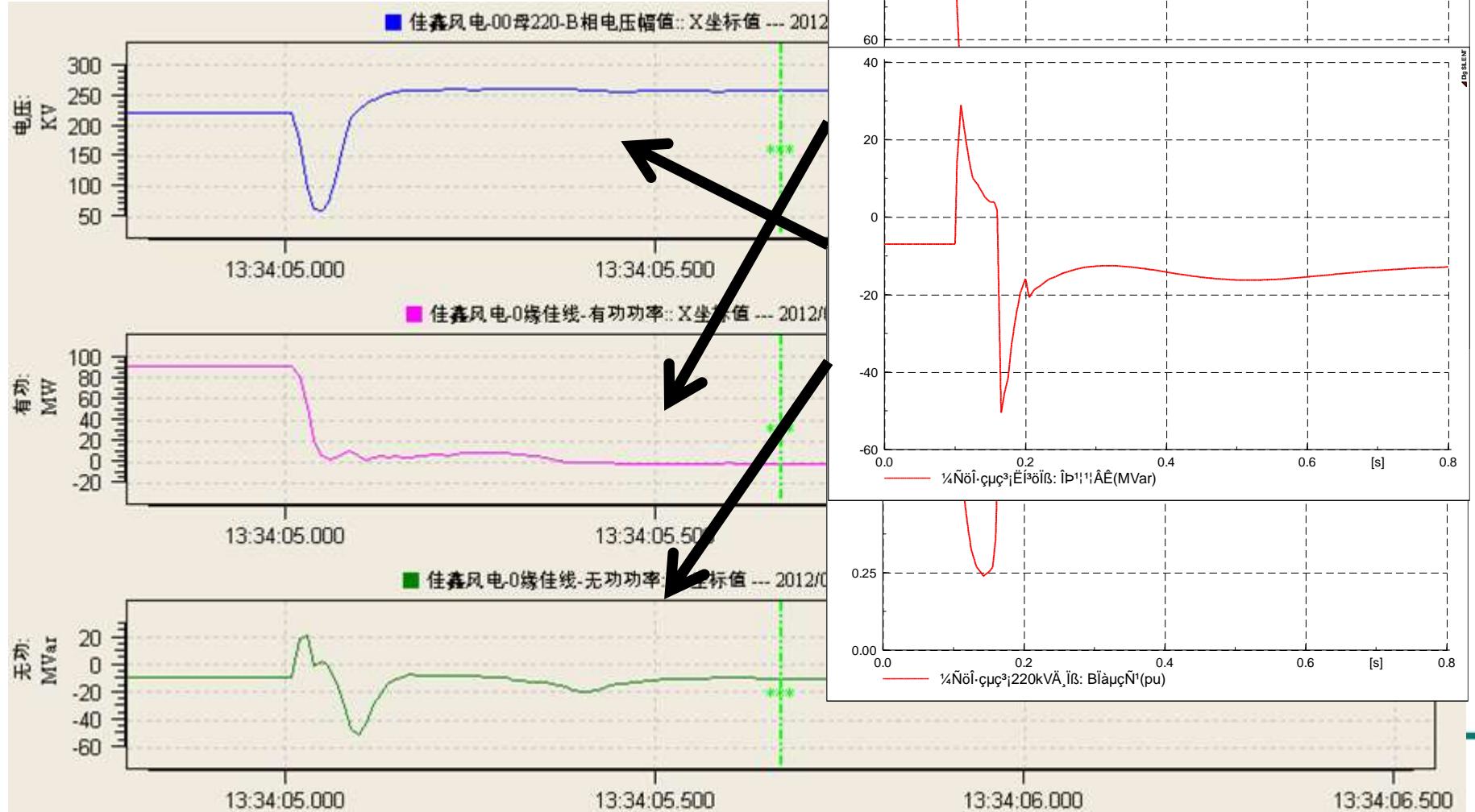
### ● *Simulation of the Accident(事故仿真)*



## 2.3 Analysis of Large Scale Wind Power Trip-off 风电大规模脱网事故分析



### ● *Simulation of the Accident(事故)*



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风电并网研究的不足与改进

# 3.1 Tools for Grid-Integration Study of Wind Power

## 风电并网研究的主要工具



- Three main analysis tools in china for wind power integration Study

### 中国三个用于风电并网研究的主要工具

- PSASP (电力系统分析综合程序)
- PSD Tools (PSD 电力系统分析软件包)
- DIgSILENT PowerFactory

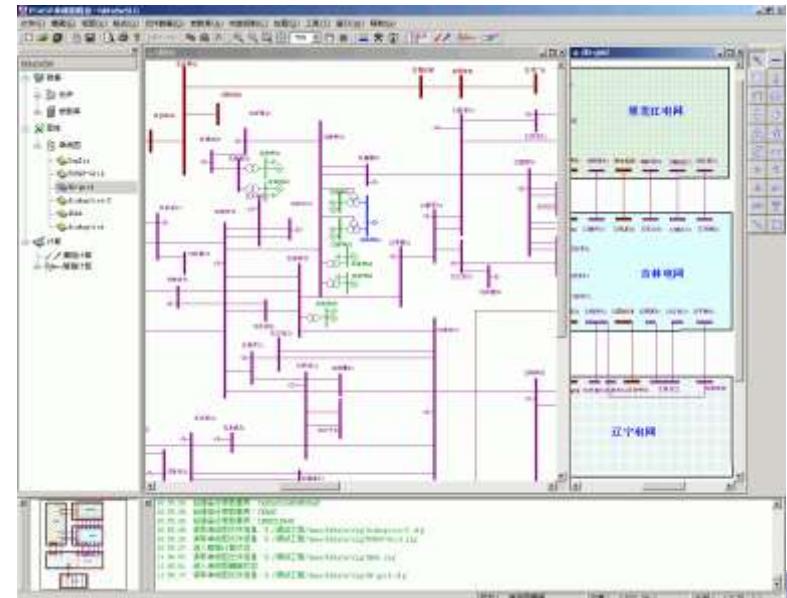
# 3.1 Tools for Grid-Integration Study of Wind Power 风电并网研究的主要工具



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## ● Power System Analysis Software Package , PSASP 电力系统分析综合程序

- A composed tool for power system analysis, developed by China EPRI.  
综合性电力系统分析软件，由中国电力科学研究院开发。
- Widely used in Power System Analysis  
广泛应用于中国的电力系统分析
- Several models of wind turbines are internal included, and user defined model is supported.  
内置了常用类型风电机组模型，具备用户自定义模型的功能



# 3.1 Tools for Grid-Integration Study of Wind Power

## 风电并网研究的主要工具



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### ● PSD(Power System Department) Tools 电力系统分析软件包

- Another composited tool for power system analysis, developed by China EPRI based on BPA program.

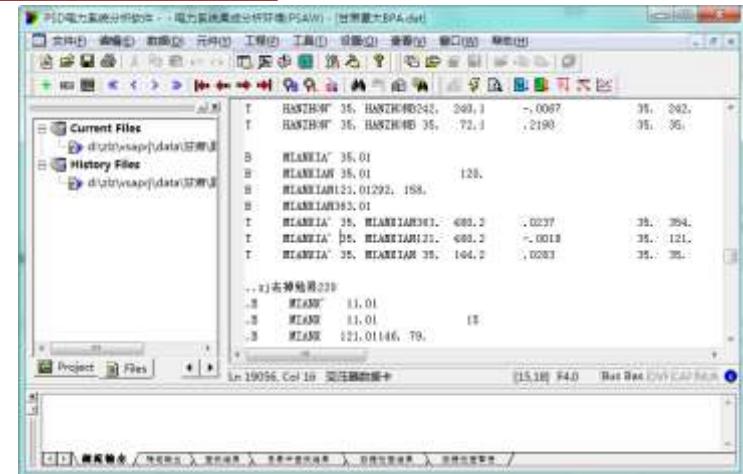
综合性电力系统分析软件，由中国电力科学研究院基于BPA开发。

- Widely used in Power System Analysis in China

广泛应用于中国的电力系统分析

- Several models of wind turbines are internal included, user defined model is **not supported**.

内置了常用类型风电机组模型，不支持用户自定义模型的功能



中国电力科学研究院

CHINA ELECTRIC POWER RESEARCH INSTITUTE

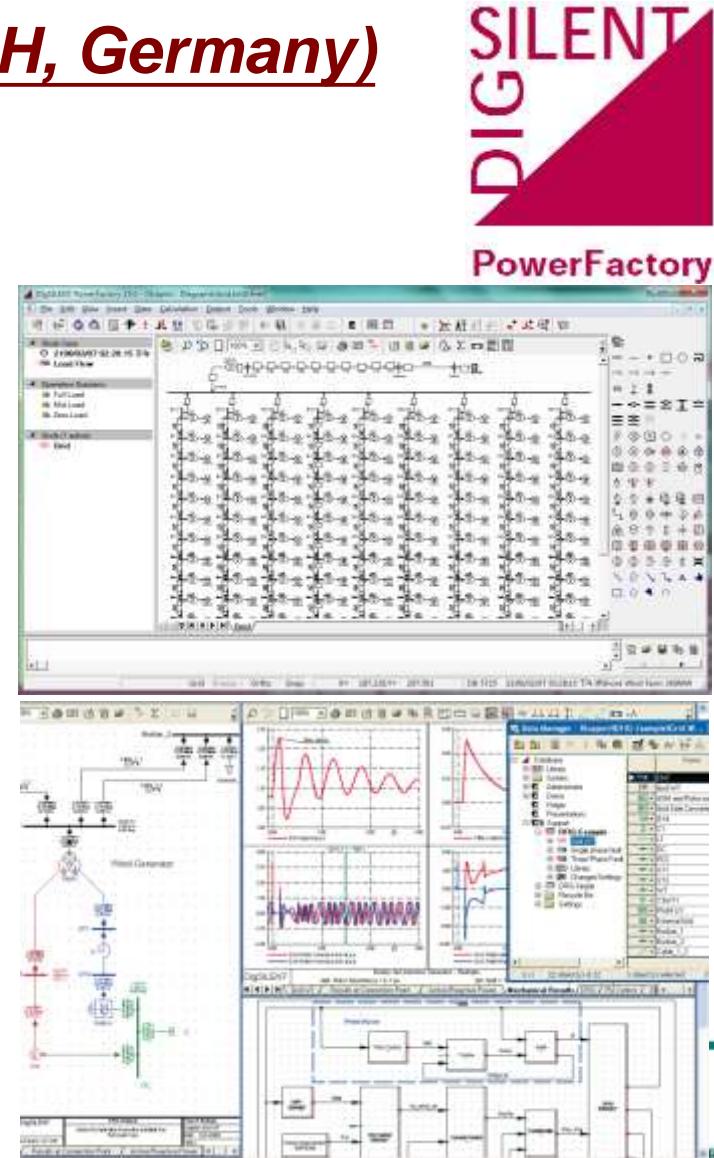
# 3.1 Tools for Grid-Integration Study of Wind Power 风电并网研究的主要工具



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## ● PowerFactory, (DlgsILENT GmbH, Germany)

- Worldwide used composited platform for power system analysis and research.  
世界范围内广泛使用的综合性电力系统分析和研究平台。
- Different kinds of models for renewable generation such as wind turbine, PV system and energy storage system.  
提供了多种新能源发电系统模型，如风电、光伏发电、储能系统等。
- Powerful user defined model tools through DSL Language.  
通过DSL语言，实现了较为强大的自定义模型功能
- Not compatible with data format of PSASP and PSD Tools  
与PSASP和PSD Tools数据格式不兼容



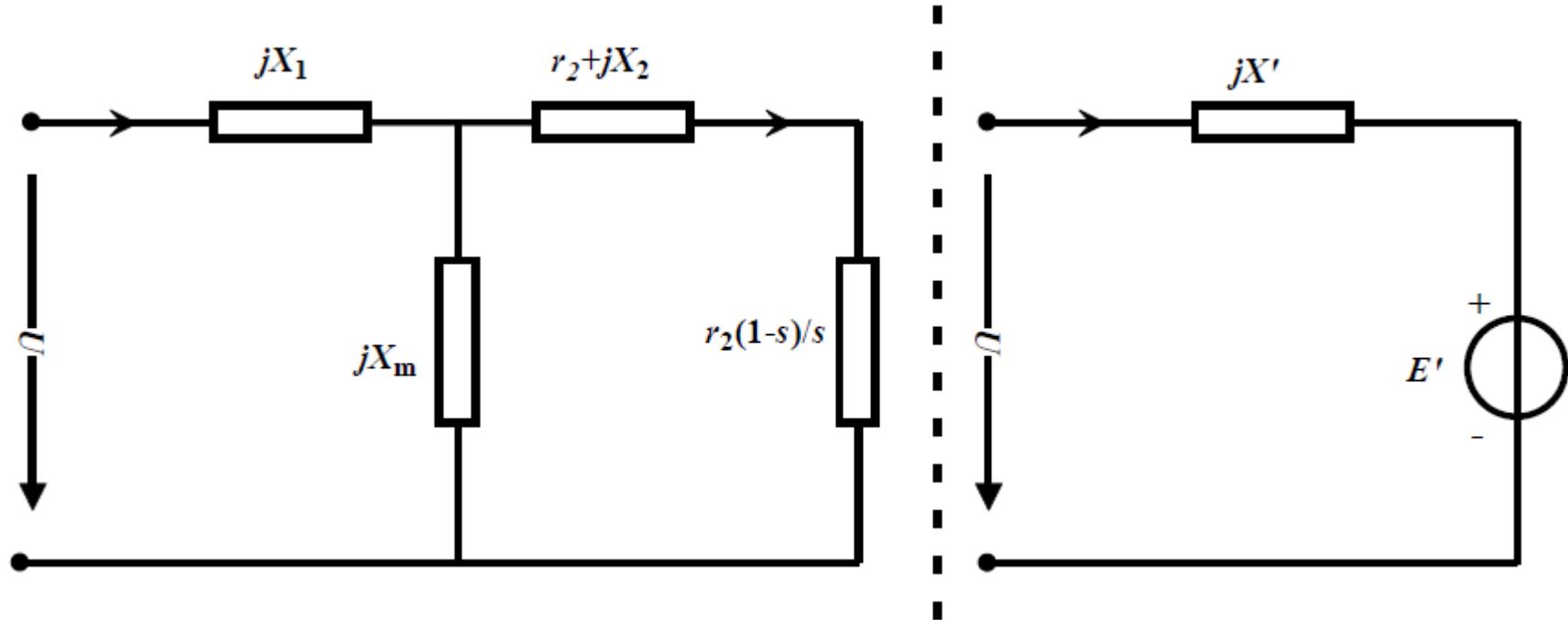
## 3.2 Models of Wind Turbines

### 风电机组并网分析模型



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#### ● Wind Turbine Models in PSASP and PSD-BPA



*Model for Induction Asynchronous Wind Turbine (Type I)*  
定桨距鼠笼式感应异步风机的模型



*Just the same as conventional induction generators*  
与传统异步发电机模型相同

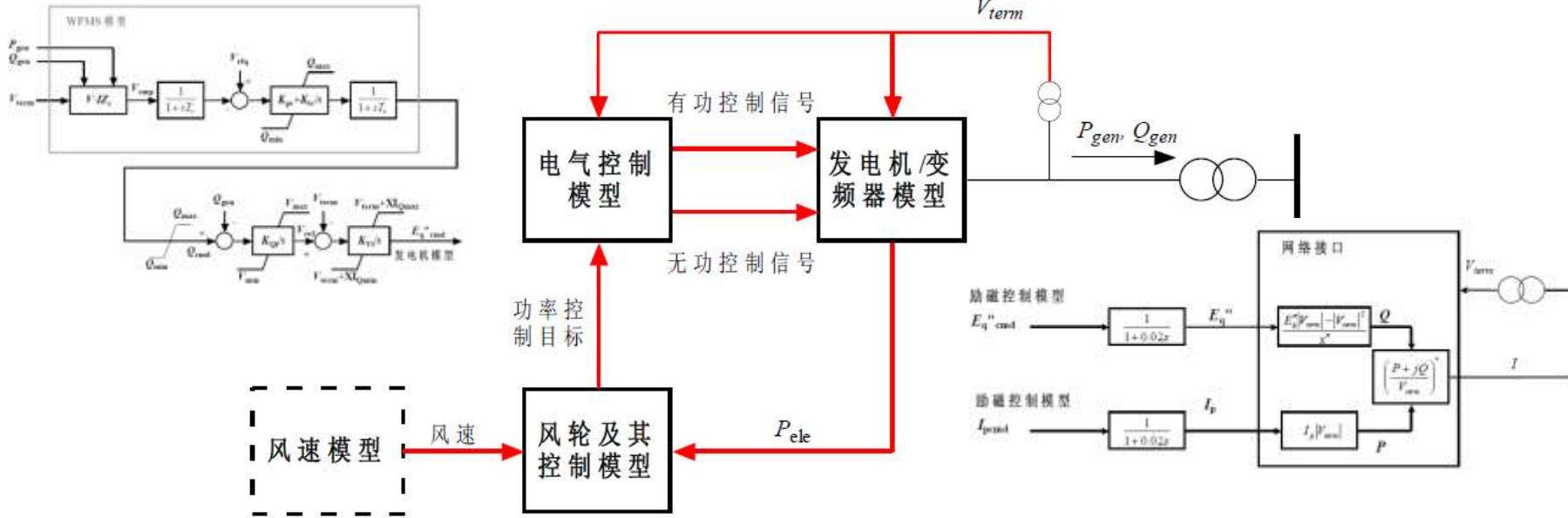
# 3.2 Models of Wind Turbines

## 风电机组并网分析模型



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### ● Wind Turbine Models in PSASP and PSD-BPA



### A Common Models for Both DFIG and PMSG (Type III & Type IV) 一种双馈直驱风电机组通用模型

- Based on GE Wind turbine model. (基于GE风电机组模型)
- A controllable current source is used to model the generator and converter. 采用受控电流源描述机网接口
- The Model of PWM converter and protection system is simplified. 对PMW变换器、保护系统模型进行了简化

## 3.2 Models of Wind Turbines

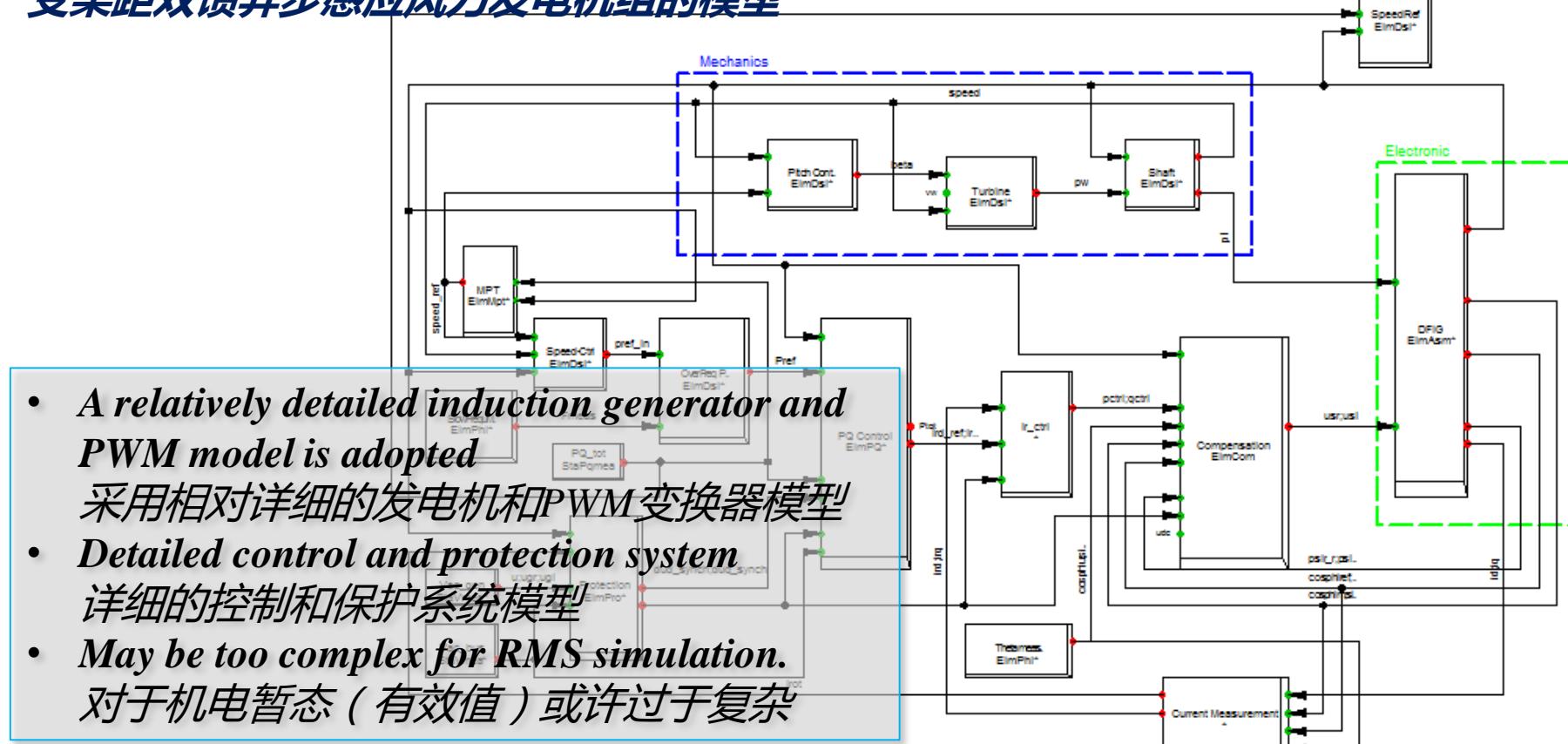
### 风电机组并网分析模型



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#### ● Wind Turbine Models in PowerFactory

*Model for doubly feed asynchronous induction wind turbine Generator (TYPE III)*  
变桨距双馈异步感应风力发电机组的模型



## 3.2 Models of Wind Turbines 风电机组并网分析模型

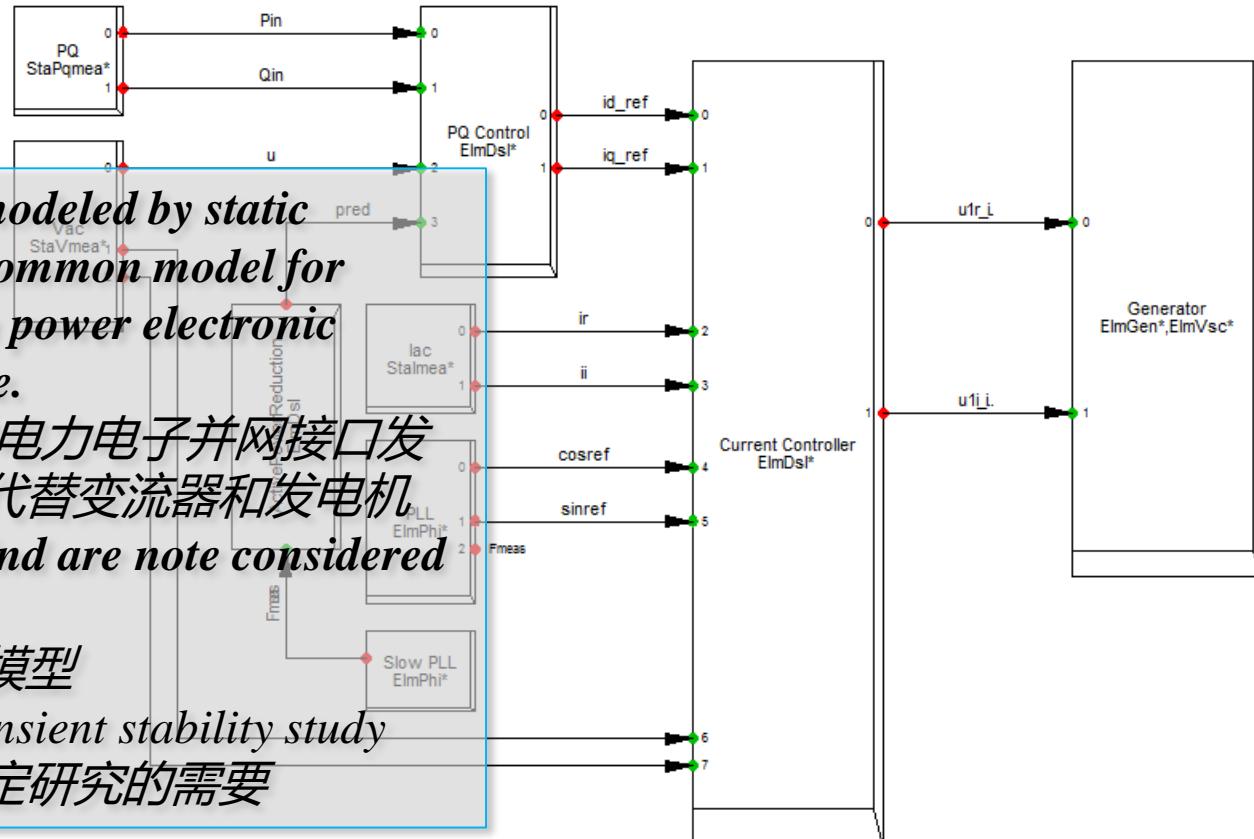


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### ● Wind Turbine Generator Models in PowerFactory

Model for wind turbine generators with full rated converter (Type IV)

全功率变频器风电机组的模型



- The grid interface is modeled by static generator, which is a common model for generation system with power electronic converter grid interface.*  
采用静态发电机(一种电力电子并网接口发电系统的通用模型)代替变流器和发电机
- The turbine and the wind are note considered in this model.*  
忽略了风轮机、风速模型
- Meet for short-term transient stability study*  
能够满足短期暂态稳定研究的需要

# Content (目 录)



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- Wind Power in China  
中国风电情况
- Study on Grid Integration of Wind Power  
风电并网研究
- Models and Tools for Grid integration study  
风电并网研究的模型与工具
- Problem and Suggested Improvement  
风电并网研究的不足与改进

# 4 Problem and Suggested Improvement

## 风电并网研究的不足与改进



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### ● About the Models of wind power(关于风电的模型)

- *How to construct a suitable model for different study purpose? (如何针对不同的研究目的，建立合适的模型)*
- *Are the current models of wind turbine correct? Or can we model different types of wind turbine by parameter adjustment?*  
现有的风电模型是否准确，能否通过参数的调整使之适应不同型号的风机？
- *How to test or identify the model parameter of wind turbine? (如何测试风电机组的模型参数)*
- *How to construct an aggregate model of a wind farm which contains lots of wind turbines working at different state? (如何建立一个风电场的聚合等值模型)*

## 4 Problem and Suggested Improvement

### 风电并网研究的不足与改进



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#### ● About the method of grid integration study 关于风电并网研究的方法

- *For planning stage grid-integration study, can we find out potential risk such as cascaded wind turbine trip off at bulk wind base, and electricity curtailment of a wind farm?*

能否在规划阶段通过并网研究发现潜在的安全和经济性问题，诸如对于大型风电基地连锁故障，可能的弃风？

- *How to evaluate the risk of voltage and frequency stability when bulk wind power integrated, for those problems we need perform a mid-long term study.*

如何评估大量风电接入后对系统电压稳定和频率稳定的影响，对于这些问题，我们需要开展中长期的分析

报告结束

Thanks!

