



山东大学

电网智能化调度与控制教育部重点实验室

Key Laboratory of Power System Intelligent Dispatch And Control Ministry of Education

# Collaborative Research on Power Systems between Shandong University and Overseas Universities

Prof. Hongtao Wang

28 July. 2014

School of Electrical Engineering  
Shandong University



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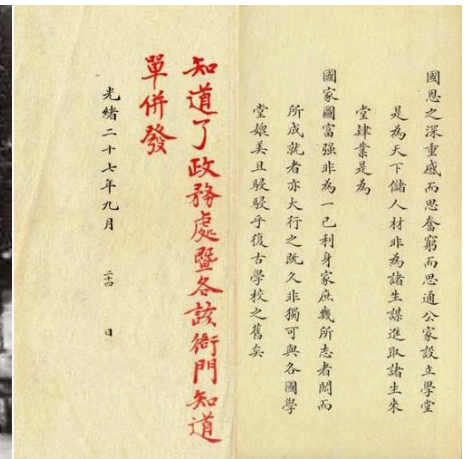
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# Outline

- Introduction of Shandong University
- Introduction of School of Electrical Engineering(Research Labs and Facilities in School of Electrical Engineering)
- Research Areas and Selected Research Topics  
Power system Restoration in School of Electrical Engineering

# History of Shandong University

- Shandong Imperial College, the former of Shandong University, established in 1901, was the 2nd national university in China.
- The new Shandong University was founded in 2000, by merging Shandong Industrial University, Shandong Medical University and Shandong University.



# Scale of Shandong University

- Over 7,000 academic, technical and administrative staffs, 60,000 full-time students;
- 42 Schools, 3 affiliated hospitals;
- Covering an area of over 533 hectares, with 8 campuses (6 campuses in Jinan, 1 campus in Weihai, 1 campus in Qingdao).





# Location of Shandong University



The main campuses locate in Jinan, Shandong, China. Jinan is the capital of Shandong Province.

Jinan locates in the east of China, 1 hour 40 mins to Beijing and 3.5 hours to Shanghai by fast train.

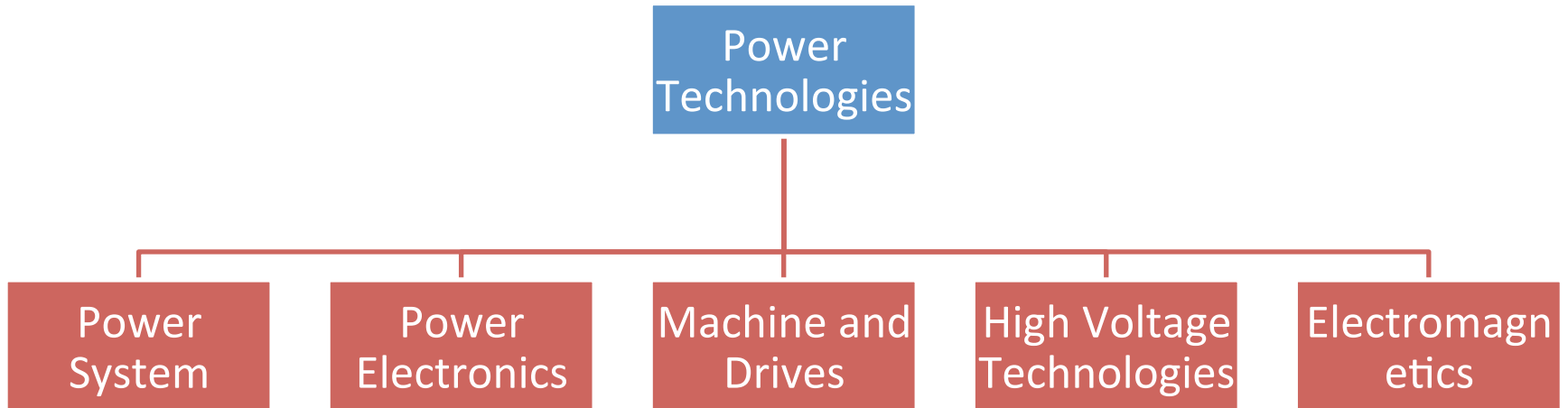
Jinan is famous for various springs inside the city.

# School of Electrical Engineering

- Locates at the Qianfoshan Campus, Jinan
- Close to city center and Qianfoshan Mountain.
- 135 staffs including 31 professors, 46 associate professors and 23 lecturers.
- 1200 undergraduate and 500 graduate students.



# Research Areas in School of EE





# Research Labs and Facilities

- Key Laboratory of Power System Intelligent Dispatch and Control (Shandong University), Ministry of Education
- 7 Research Institutions
- 4 Provincial Engineering Technology Centers
- Power system dynamic model and simulation platform, RTDS, integrated substation automation system, advanced digital power system simulator.





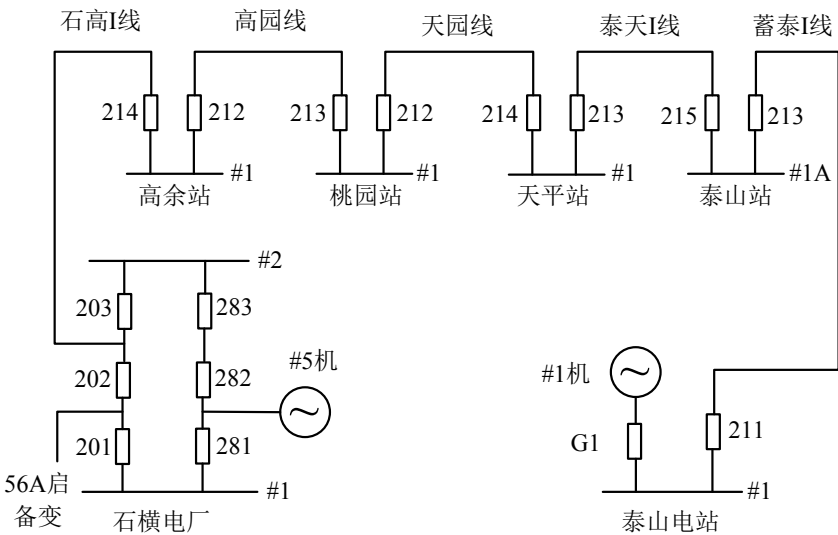
# Power system restoration and power grid self-healing

- Power system black start field test in Shandong provincial power grid.
- Developing power system restoration aided decision/dispatching/control system
- Book on power system restoration 《Power system restoration theory and technology 》

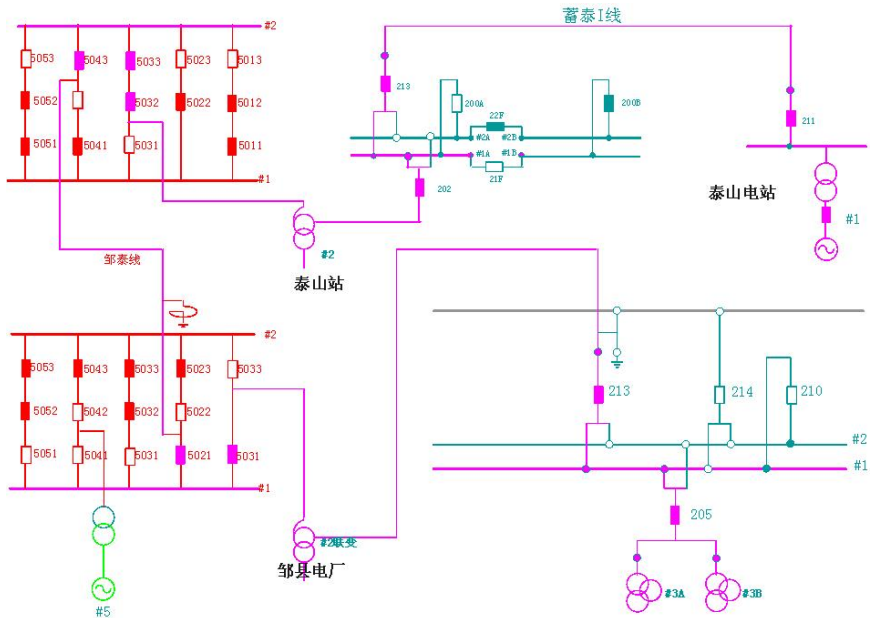
# Power system black start field test

Grid	Voltage (kV)	Capacity of BSU (MW)	Maximum electric motor (MW)	Length of lines (km)	Date of filed test	Remarks
North China	220	200	2	92	2000.5	
Hubei	220	35	5.8	168	2002.1	
Gezhouba	220	125			2002.4	
Inner Mongolia	220	180	2.5	56.6	2004.11	
Hainan	220	5			2005.9	Total black out
Shandong	220	250	5.5	101	2009.3	
Shandong	500	250	6.6	140	2012.5	failure
Shandong	500	250	6.6	140	2012.11	success

Shandong Power Grid 220kV 101  
km transmission lines 330MVA  
Thermal Unit involved in black  
start



Shandong Power Grid 500kV 140  
km transmission lines 660MVA  
Thermal Unit involved in black  
start



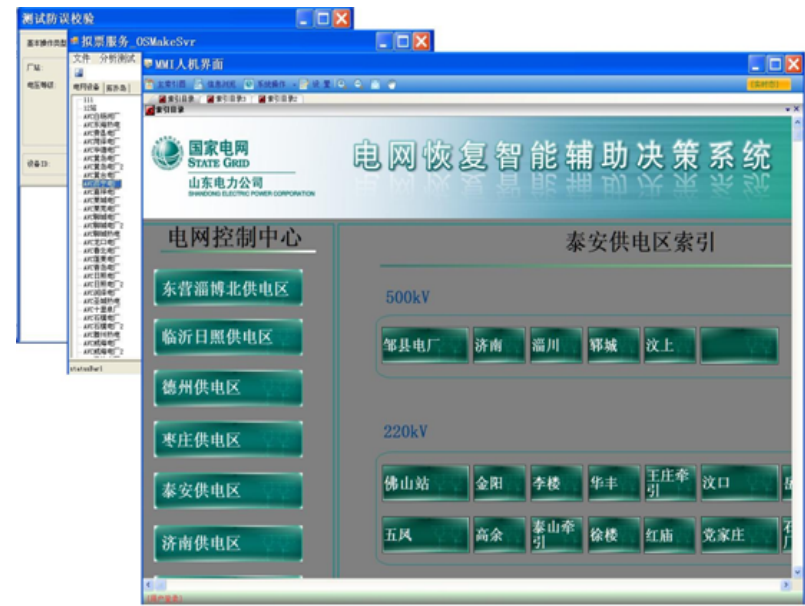
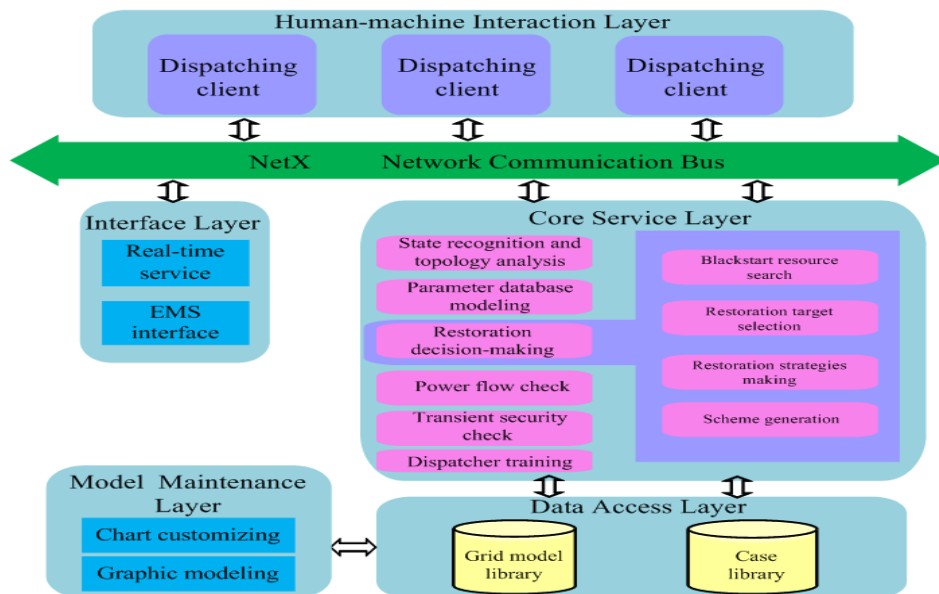




# Developing Navigator type Power system restoration supporting systems

## Main Features:

- The whole restoration process decision are supported involving generator black-start, power grid reconfiguration, load restoration.
- The whole restoration process could be validated such as self-excitation, transient overvoltage, harmonic analysis voltage drop of large induction motor starting, etc.
- The whole levels of dispatching could cooperate within one system and coincident real time data.



# 电力系统恢复理论与技术

刘玉田 王洪涛 叶华 著

科学出版社

## Main contents

- Black start
- Network reconfiguration
- Load restoration

## Main Theories

- Leader-follower hierarchical
- Group intelligent
- Pareto-optimal
- Expert system technology

## Special Practice

- Grid black start experiment
- AC/DC system restoration
- Restoration considering new energy power generation

Power system  
restoration theory  
and technology

# Power system restoration and power grid self-healing

## 1. Project:

- National Natural Science Foundation of China
- National High-tech Research and Development Program of China(863 Program)

## 2. Collaboration:

- Shandong provincial electrical dispatching & control center
- Manchester University of UK
- Jinan True Technology Co.

**We are Looking forward to further collaborations with US universities or US company!**



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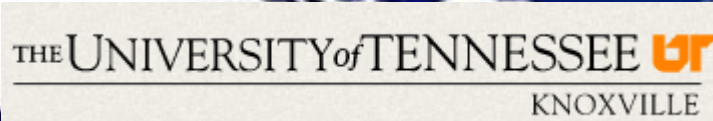
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# Thanks for your attention!

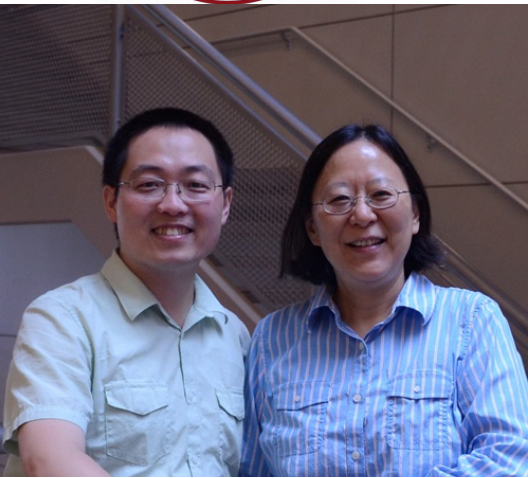
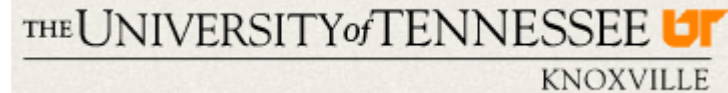
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# US/China international collaboration



# Collaboration with University of Tennessee, Knoxville



Shandong University  
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Power System  
Intelligent Dispatch  
and Control of  
Ministry of Education



**Prof. Yilu  
Liu**

- **Governor's Chair** at UTK and Oak Ridge National Laboratory (ORNL).

- **Exchange scholars:**

Changgang Li: visiting scholar. 2012-2014  
Changqing Zhu: visiting scholar . 2012-2013  
Chunjuan jia: visiting scholar . 2012-2013  
Wenjing Hu: visiting scholar . 2012-2013

- **Participate in US Projects:**

“Synchrophasor-based power system dynamic modeling for stability estimation” (project No. P39.015) supported by Electric Power Research Institute (EPRI), and project “High-performance hybrid simulation/measurement-based tools for proactive operator decision-support” (project No. DE-FOA-0000729) supported by Department of Energy (DOE) and EPR.

# Collaboration with University of Texas at Arlington



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and Control of  
Ministry of Education

- **Exchange scholars:**

Ming Yang: visiting scholar. 2011-2012

Kejun Li: visiting scholar . 2010-2011

Huibin Sui: visiting scholar . 2009-2010

- **Collaboration research area:**

**Power system operation, control and stability**

- **Published Paper Jointly:**

1. Probabilistic Short-Term Wind Power Forecast Using Componential Sparse Bayesian Learning.
2. Design and Implementation of SOPC-Based Frequency Variable Inverter.
3. Study on Mode-Switching Control of TCSC Based on Conditional Firing of Thyristor, IEEE Transactions on Power Delivery, Volume 26, Issue 2



**Prof. Wei-Jen Lee**

- **IEEE Fellow**
- Fellow of IEEE
- Vice Chair-  
Technical of the  
IEEE/IAS, ICPSD

# Collaboration with University of GeorgiaTech



- Shandong University  
Key Laboratory of Power  
System Intelligent Dispatch  
and Control of Ministry of  
Education



**Prof. Miroslav Begovic**

- Chair of the Electrical  
Energy Technical  
Interest Group.
- PES President

- **Exchange scholars:**  
Zhihao Yun: visiting scholar. 2010-2011
- **Collaboration research area:**  
**Power system reactive power/ voltage optimization**



# Collaboration with University of Wisconsin-Madison



- Shandong University  
Key Laboratory of Power  
System Intelligent Dispatch  
and Control of Ministry of  
Education



**Prof. Hiskens**



- IEEE Fellow
- Fellow of Engineers Australia
- Chartered Professional Engineer in Australia.
- Professor at the University of Wisconsin-Madison. (2002-2008)
- Exchange scholars:  
Wen Zhang: visiting scholar. 2006-2007
- Collaboration research area: Wind power integration to power system and reactive power optimization.
- Published Paper: Xiaodong Chu, Wen Zhang, Tochi Nwachukwu, and Ian A. Hiskens, "Characterization of Daily Wind Farm Power Fluctuations Using Wavelet Transform", International Conference on Natural Computation (ICNC'08)

# Collaboration with University of Connecticut



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**Dr. Peng  
Zhang**

- Assistant Professor, Department of Electrical and Computer Engineering, University of Connecticut

- **Exchange scholars:**  
Hua Ye: visiting scholar. 2014-2015
- **Collaboration research area:**  
**Renewable energy integration planning and operation risk assessment**



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## ➤ Intelligent Restoration Decision-Theoretical Method

- The problem of restoration control and decision : multi-layer, multi-objective, nonlinear and time-varying.

- The proposed theoretical system of control and decision during power system restoration

Blackout in Worldwide

Distributed decision: leader-follower hierarchical decision theory

Multi-attribute: group multi-attribute decision theory

Multi-objective: Pareto-optimal decision theory

- Intelligent decision support system for restoration is developed to assist making restoration plan for power grid and plants.



## ➤ Intelligent Restoration Decision - Process Simulation

- Power system restoration process involves many extreme operation modes. Currently, There is no comprehensive simulation tools that is available.
- The whole restoration process are studied and proposed, involving generator black-start, self-excitation, transient overvoltage, harmonic analysis voltage drop of large induction motor starting, etc.
- Integrated into Dispatcher Training System and Intelligent Restoration Decision Support System . Have been used to verify and guide the black start plan in real grid for many times.

