2016 International Conference on Probabilistic Methods Applied to Power Systems

Conference Program

Organizers: Tsinghua University
Chongqing University

清華大學 TSINGHUA UNIVERSITY

重慶大學 CHONGQING UNIVERSITY

October 16-20, 2016
Beijing, China

WELCOME FROM CHAIR

On behalf of the Organizing Committee, it is our great pleasure to welcome you to attend the 2016 International Conference on Probabilistic Methods Applied to Power Systems (PMAPS 2016), which is jointly organized by Tsinghua University and Chongqing University in China. The PMAPS 2016 will be held in Beijing, October 16-20, 2016.

The theme of the PMAPS 2016 is "Shaping the Future of Probabilistic Applications". 184 papers from 29 countries will be presented at the conference including 98 student papers. 131 reviewers participated in the paper review process. The experts in the PMAPS fields across the world will attend the conference. The plenary session, 4 panel and invited paper sessions and 41 regular paper sessions will provide a platform for the attendees to demonstrate their achievements and exchange their ideas. We will also organize a whole day's tutorial on October 16, 2016, which will benefit those who want to acquire basic and advanced knowledge in power system reliability. We are pleased to see that a considerable number of students from different countries have expressed their significant interests in the PMAPS fields. To acknowledge and encourage the excellence of students in the areas of probabilistic methods applied to power systems, the "Best Student Paper Awards" are established at the 2016 PMAPS conference. The official title of the awards will be announced at the awarding ceremony.

Your attendance will not only help you acquire useful information, meet old friends and establish new networks, but also greatly enhance the success of the conference. A technical tour to a big micro-grid project site and a Great Wall tour will give you long time lasting memories.

We want to express our sincere thankfulness to the authors, paper reviewers, session chairs, organizing committee members and all volunteers for their contributions. Special thanks go to the board directors of the PMAPS International Society for their guidance.

We believe that the PMAPS 2016 will be your unforgettable and pleasant experience.

Wenyuan Li and Lin Cheng

Co-chairs of the 2016 International Conference on Probabilistic Methods Applied to Power Systems

September 8, 2016

ACKNOWLEDGMENTS

The organizing committee of the 2016 International Conference on Probabilistic Methods Applied to Power Systems (PMAPS 2016) would like to thank the following sponsors for their generous support:

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重庆大学电气工程学院 School of Electrical Engineering, Chongqing University

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Journal of Modern Power Systems and Clean Energy MPCE

CEES 星能电气 Electric Energy Star

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CSEE Journal of Power and Energy Systems

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We would like to sincerely thank the following PMAPS 2016 paper reviewers for their valuable time:

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ORGANIZERS

Tsinghua University

Tsinghua University was established in 1911. At present, the university has 20 schools and 54 departments with faculties in science, engineering, humanities, law, medicine, history, philosophy, economics, management, education and art. The University has now over 46,200 students, including 15,636 undergraduates, 18,661 post-graduates and 11,903 doctor candidates. As one of China's most renowned universities, Tsinghua has become an important institution for fostering talent and scientific research, which ranks the 24th place in the QS World University Rankings of 2016.

- **Department of Electrical Engineering, Tsinghua University**

The Department of Electrical Engineering at Tsinghua University was founded in 1932. It currently has five research fields. They are power system and its automation, high voltage and insulation technology, electrical machinery and electric equipment, electrical theory and new technology, power electronics and power drives respectively. About 120 bachelors, 80 masters and 40 PhDs graduate from the department every year. The Electrical Engineering Discipline has been ranking the first place since the first evaluation of disciplines by China's Ministry of Education. There are 128 full time staffs and 98 of them are faculties. The faculties include one academician of the Chinese Academy of Science and the foreign academician of the Royal Swedish Academy of Engineering Sciences, one academician of the Chinese Academy of Engineering, one academician of the UK's Royal Academy of Engineering, four IEEE Fellows and six IET Fellows.

- **State Key Laboratory of Control and Simulation of Power System and Generation Equipment of Tsinghua University**

With the motto of "conscientious academics and honest behavior", the Department of Electrical Engineering aims to take leadership affecting broad aspects of the electrical engineering discipline, power engineering industry and society. The research work is strongly connected with the State Key Laboratory of Control and Simulation of Power System and Generation Equipment, which contains nine research labs and three experimental centers and was accredited as "Excellent" (A) twice in the assessment held in 2003 and 2008 respectively by the Ministry of Science and Technology. Many probabilistic reliability researches and applications have been performed, including Large-scale Multi-area Operational Reliability, Reliability Analysis on Integration of Intermittent Power Supply, and Power System Reliability Assessment with Electric Vehicle Integration. The recent work focuses on the topics of energy and environment. From energy production, energy transmission, energy consumption to energy market, a multi energy system including electricity network, gas network and heating network is formed. Energy Internet Research Institute of Tsinghua University was thereby established in 2015 in the pursuit of effective utilization of clean energy and reliable energy supply.

Chongqing University

Chongqing University (CQU), located in Chongqing city, Southwest of China, is a famous university and a member of the "Excellence League". It is one of the "211 Project" and "985 Project" universities in China. Founded in 1929, CQU now has six main areas of Science, Social Sciences, Humanities, Engineering, Built Environment, and Information Science & Technology. The departments in Built Environment, Engineering, Technology, and Business disciplines are ranked in the front nationally.

- **School of Electrical Engineering, Chongqing University**

The School of Electrical Engineering (SEE), established in 1936, is one of the oldest and most famous schools in CQU and has reached high reputations at home and abroad. The electrical engineering discipline in the SEE holds important national platforms, including a state key laboratory, a national "211 Project" center, a national teaching base, and a national "111 Project" base, which have provided significant activities in academic researches, talent trainings, and international cooperation. There are many high level faculties, including a Foreign Academician of the Chinese Academy of Engineering and many outstanding young professors. The SEE has also developed a creative research group named by the national Natural Science Foundation and a national teaching team named by China's Ministry of Education. In the past 2 rounds of China's discipline ranking assessment in 2006 and 2012, the electrical engineering discipline in the SEE ranks TOP 5 in more than 300 similar disciplines in China.

- **State Laboratory of Power Transmission Equipment & System Security and New Technology**

The state laboratory of power transmission equipment & system security and new technology was established in 2007. The lab has a strong research group, including Academicians of Chinese Academy of Engineering, leading scientists of the national "973" project, awardees of National Outstanding Youth Funds, and professors in the Yangtze River Scholar Program. The lab distinguishingly stands out in power transmission equipment security, state monitoring of electrical equipment, reliability and security of power systems, and novel electrical technologies. It has cultivated a great number of highly qualified talents and become an important base for academic and engineering researches. In recent years, the lab has acquired 3 second-class awards of National Science and Technology Awards, 8 first-class, 14 second-class and 9 third-class awards of Provincial Technology Awards. 131 invention patents have been approved and over 1900 SCI and EI indexed papers have been published in journals.

- **Power and Energy Reliability Research Center of Chongqing University**

Power system reliability researches in CQU started in 1970s. The Power and Energy Reliability Research Center of CQU was established in 2013. The team members in the center have made systematic studies and contributions in power system reliability for many years, including theories, methods, models, data analysis and engineering applications. Led by a Foreign Academician of the Chinese Academy of Engineering, the center has been well recognized by peers nationally and internationally. It also has a strong advisory committee that includes five foreign and Chinese academicians and three foreign IEEE fellows. The main research directions include risk assessment of smart grids, probabilistic power system planning, asset management in power systems, applications of big data technology, power system information security, and operations of power systems with renewable energy and power electronic devices. In recent years, the team members in the center have received several international awards from IEEE PES and PMAPS international Society, 1 first-class, 10 second-class and 10 third-class awards of Provincial Technology Awards in China. Over 320 SCI and EI indexed papers, 3 English monographs, and 10 Chinese monographs have been published. 2 American patents, 3 Canadian patents and over 30 Chinese patents have been authorized.

PMAPS HISTORY

PMAPS was first held in June, 1986, in Toronto, Canada, organized by Samy Krishnasamy, of what was then Ontario Hydro. It was called the International Symposium on Probabilistic Methods Applied to Power Systems. There were about 75 papers presented, and about 180 attendees from 15 countries attended the Symposium. At that time a temporary International Council on Probabilistic Methods Applied to Power Systems (PMAPS) was formed with members from North America, Europe and Asia. The purpose of the Council was to assist in the selection of venues for the conferences and to provide continuity.

The surprising large interest in attending the first symposium resulted in the second symposium, held in September 1988 in Oakland, California, organized by Samy Krishnasamy and Richard Kennon of the Electric Power Research Institute. There were 45 papers presented at the Oakland Symposium, with over 150 attendees.

The 3rd PMAPS Symposium (from then on it is called Conference) was held in July 1991, in London, England, organized by Professor Ron Allan and sponsored by IEE. There were 59 papers included in the proceedings.

The 4th PMAPS Conference was held in September 1994, in Rio de Janeiro, Brazil, sponsored by Eletrobras and the World Energy Council. There were 71 papers included in the proceedings with about 150 attendees. Four tutorials were organized.

The 5th PMAPS Conference was held in September 1997, in Vancouver Canada, organized by Fred Turner of BC Hydro. There were 92 papers in the proceedings, and attendance was about 180. Also, 2 panel discussions and 1 tutorial were organized for this conference. Immediately after the fifth PMAPS in Vancouver, the PMAPS International Society was incorporated with Roy Billinton, Samy Krishnasamy and Fred Turner as directors. The PMAPS International Society is comprised of the directors, the local organizing committee chair of the immediately preceding conference, and the local organizing committee chair of the next conference.

The 6th PMAPS was held in September, 2000, in Madeira Island, Portugal, organized by Vladimiro Miranda of INESC Porto and the University of Porto. There were 100 papers included in the proceedings plus an additional 16 in a small parallel event called RIMAPS'2000 aimed at European young researchers. Professor Ron Allan was recognized with a special honoring for his work in the development of probabilistic methods applied to power systems.

The 7th PMAPS was held in September, 2002, in Naples Italy, organized by Alfredo Testa of the University of Naples and Guido Carpinelli of the University of Cassino. There were 150 papers included in the proceedings; 3 tutorials and 9 special sessions were also organized for this conference. Professor Roy Billinton was recognized with a special honoring for his work in the development of probabilistic methods applied to power systems.

The 8th PMAPS was held in September, 2004, in Ames, Iowa USA at the Iowa State University, organized by Jim McCalley of ISU. There were 173 papers included in the proceedings, and 3 tutorials, 2 workshops, and 11 special sessions were organized for the conference. The conference was attended by over 200 people. Dr. John Endrenyi was recognized with a special honoring for his work in the development of probabilistic methods applied to power systems.

The 9th PMAPS was held in June, 2006, in Stockholm, Sweden, at the Royal Institute of Technology (KTH), organized by Lina Bertling. There were 192 papers from 35 countries included in the proceedings, and 3 tutorials, 6 workshops, and 38 special sessions were organized for the conference. The conference was attended by 318 people.

The 10th conference was hosted in Rincón, Puerto Rico, by the University of Puerto Rico - Mayaguez. There were 86 papers presented and 101 attendees from 30 countries. Professor Chanan Singh was recognized with a special honoring for his work in the development of probabilistic methods applied to power systems.

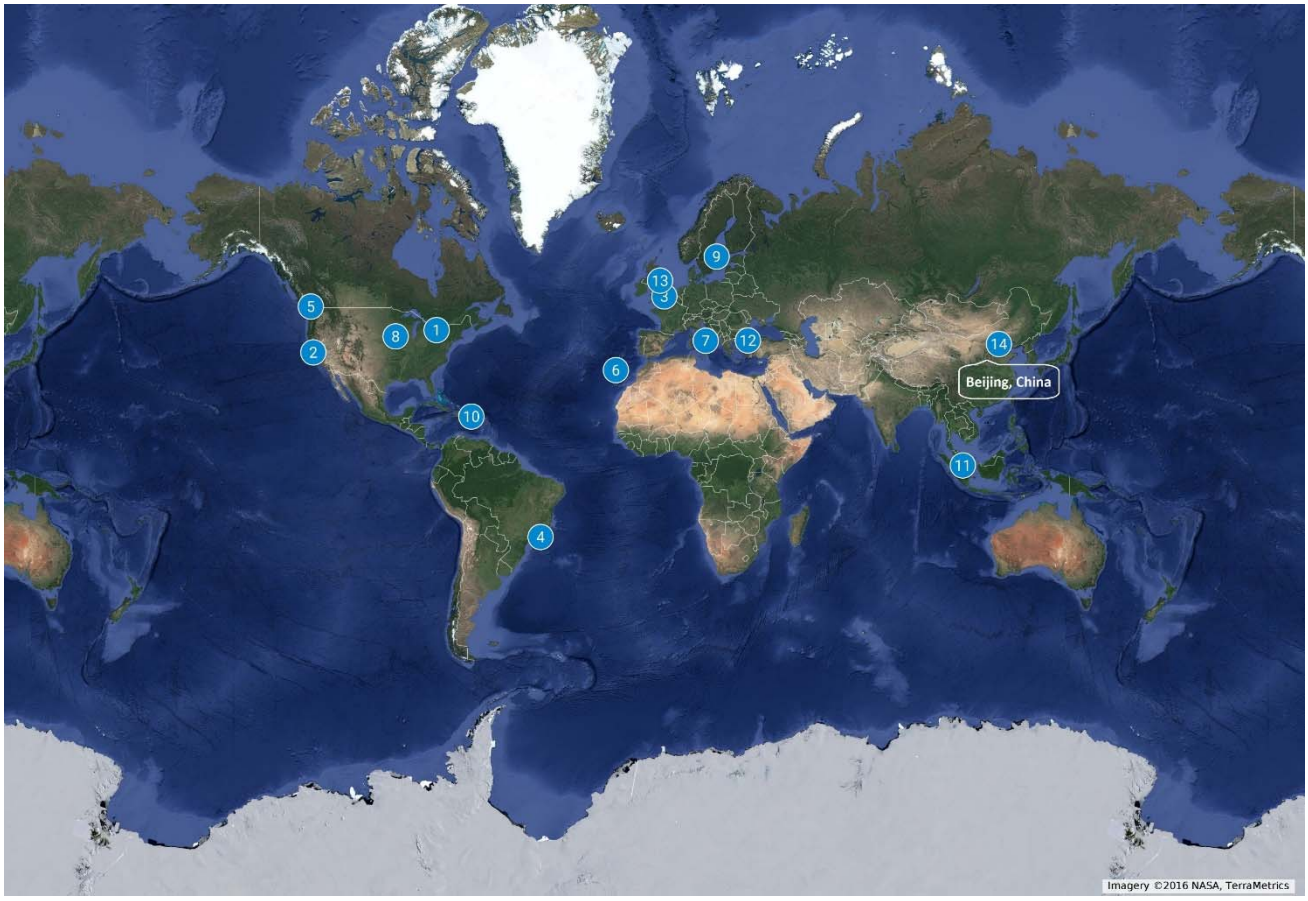
The 11th conference, PMAPS 2010, was organized by the IEEE Power & Energy Society (PES) Singapore Chapter, with the IEEE PES as the technical co-sponsor and the Nanyang Technological University & National University of Singapore as co-organizers. The conference received 184 full paper submissions, of which 137 have been accepted and scheduled for presentation. The full paper submissions came from 26 countries, and about 165 delegates have registered for the conference, of which about 64 are student delegates. Professor Armando M. Leite da Silva was recognized with a special honoring for his work in the development of probabilistic methods applied to power systems.

The 12th conference, PMAPS 2012, was held in Istanbul at Istanbul Technical University, organized by Aydogan Ozdemir. The conference received 312 full paper submissions, of which 197 have been scheduled for presentation. 177 papers were presented. 233 delegates and 45 accompaniers from 50 countries have registered for the conference. Professor Wenyuan Li was recognized with a special honoring for his work in the development of probabilistic methods applied to power systems.

The 13th conference, PMAPS 2014, was held at Durham University, organised by Chris Dent. The conference received 139 full paper submissions, of which 102 were presented. 138 delegates and 7 accompaniers from 33 countries registered for the conference. Professor George Anders received the PMAPS Merit Award for his work in the development of probabilistic methods applied to power systems.

World Wide PMAPS

1	1986	Toronto, Canada, S. Krishnasamy, Ontario Hydro
2	1988	Oakland, USA, S. Krishnasamy & R. Kennon, EPRI
3	1991	London, England, R. Allan, IEE
4	1994	Rio de Janeiro, Brazil, Eletrobras & World Energy Council
5	1997	Vancouver, Canada, F. Turner, BC Hydro
6	2000	Madeira Island, Portugal, V. Miranda, INESC Porto & Univ. of Porto
7	2002	Naples, Italy, A. Testa, Univ. of Naples, G. Carpinelli, Univ. of Cassino
8	2004	Ames, USA, J. McCalley, Iowa State University
9	2006	Stockholm, Sweden, L. Bertling, Royal Institute of Technology
10	2008	Rincón, Puerto Rico, Agustin Irizarry Rivera, Univ. of Puerto Rico
11	2010	Singapore, IEEE PES & IEEE PES Singapore Chapter & Nanyang Technological University & National University of Singapore
12	2012	Istanbul, Turkey, A. Ozdemir, Istanbul Technical University
13	2014	Durham, UK, Chris Dent, Durham University
14	2016	Beijing, China, Wenyuan Li, Chongqing University, Lin Cheng, Tsinghua



PROGRAM AT A GLANCE

Time	Sunday October 16, 2016. Welcome & Tutorial	
07:30	Registration	**Start Registration** Building 2 Hall
08:40-08:45		**Welcome** by Chair Building 8 Meeting Room 5
08:45-10:10		**Tutorial-I** First Part by Professor Roy Billinton Building 8 Meeting Room 5 Power System Reliability Evaluation
10:10-10:30		**Café Break**
10:30-12:00		**Tutorial-I** Second Part by Professor Roy Billinton Building 8 Meeting Room 5 Power System Reliability Evaluation
12:00-14:00		**Lunch** Coffee Shop, Friendship Palace First Floor
14:00-15:30		**Tutorial-II** by Professor Armando Leite da Silva Building 8 Meeting Room 5 Applications and Researches in Power System Reliability Assessment
15:30-15:50		**Café Break**
15:50-17:20		**Tutorial-III** by Professor Vladimiro Miranda Building 8 Meeting Room 5 Computational Intelligence, Information Theoretic Learning and Auto-encoding Applied to Probabilistic Modeling in Smart Grids and Systems with Renewables
17:30-20:00		**Welcome Reception** Yashi Restaurant, Grand Building First Floor

Time	Monday October 16, 2016. Plenary Speech & Panel and Invited Paper Session (P&IS)	
07:30	Registration	**Start Registration**
08:40-09:00		**Opening Ceremony** Building 7 Meeting Room 1&2
09:00-09:45		**Plenary Speech-I** by Professor Goran Andersson Building 7 Meeting Room 1&2 Research Challenges of the Future Electric Power System
09:45-10:15		**Café Break**
10:15-11:00		**Plenary Speech-II** by Professor Xiaoxin Zhou Building 7 Meeting Room 1&2 Energy Transition and Power System Evolution in China
11:00-11:45		**Plenary Speech-III** by Professor James McCalley Building 7 Meeting Room 1&2 Co-optimized Expansion Planning Applications and Uncertainty
12:00-14:00		**Lunch** Juheyuan Restaurant, Friendship Palace First Floor
14:00-16:00	**P&IS 1** Building 7 Meeting Room 1 Probabilistic Methods and Tools in Power Systems	**P&IS 2** Building 7 Meeting Room 2 Probabilistic Applications in Utilities

16:00-16:20		**Café Break**	
16:20-17:50		**P&IS 3** Building 7 Meeting Room 1 Cyber-physical Risk of Power Systems	**P&IS 4** Building 7 Meeting Room 2 Big Data Applications in Power Systems

Time	**Tuesday October 18, 2016. Regular Paper Session (RPS)**		
08:00	**Registration**	**Start Registration**	
08:30-10:10		**RPS 1** Building 8 Meeting Room 2 Cascading Failures in Power Systems	**RPS 2** Building 8 Meeting Room 3 Stochastic Optimization and Simulation(1)
		RPS 3 Friendship Palace Conference Room 1 Forecast Techniques in Power Systems	**RPS 4** Friendship Palace Conference Room 2 Stability of Power Systems
		RPS 5 Friendship Palace Conference Room 3 Power System Operations	**RPS 6** Friendship Palace Conference Room 4 Power System Optimization
10:10-10:30		**Café Break**	
10:30-11:50		**RPS 7** Building 8 Meeting Room 2 Identification Analysis	**RPS 8** Building 8 Meeting Room 3 Probabilistic Assessment in Power
		RPS 9 Friendship Palace Conference Room 1 Stochastic Optimization and Simulation(2)	**RPS 10** Friendship Palace Conference Room 2 Uncertainties of Solar Power
		RPS 11 Friendship Palace Conference Room 3 Equipment and System Failures(1)	**RPS 12** Friendship Palace Conference Room 4 Equipment and System Failures(2)
12:00-14:00		**Lunch** Juheyuan Restaurant, Friendship Palace First Floor	
14:00-15:40		**RPS 13** Building 8 Meeting Room 2 Power System Planning Considering Reliability	**RPS 14** Building 8 Meeting Room 3 Probabilistic Analysis in Demand Side Management
		RPS 15 Friendship Palace Conference Room 1 Probabilistic Power Flow and Applications	**RPS 16** Friendship Palace Conference Room 2 Reliability of Transmission Systems
		RPS 17 Friendship Palace Conference Room 3 Reliability Assessment of Smart Grids(2)	**RPS 18** Friendship Palace Conference Room 4 Reliability Evaluation of Distribution Systems and Micro Grids
15:40-16:00		**Café Break**	
16:00-17:20		**RPS 19** Building 8 Meeting Room 2 Reliability Assessment of Smart Grids(1)	**RPS 20** Building 8 Meeting Room 3 Reliability Techniques for Power Systems
		RPS 21 Friendship Palace Conference Room 1 Risk and Reliability of Power Systems	**RPS 22** Friendship Palace Conference Room 2 Risk Assessment and Warning
		RPS 23 Friendship Palace Conference Room 3 Risk Management and Decision-making(1)	**RPS 24** Friendship Palace Conference Room 4 Load Forecasting
18:00-21:00		**Banquet Dinner** Yashi Restaurant, Grand Building First Floor	

Time	Wednesday October 19, 2016. Regular Paper Session (RPS)		
08:00	Registration	**Start Registration**	
08:30-10:10		**RPS 25** Building 8 Meeting Room 2 Correlations in Power Systems	**RPS 26** Building 8 Meeting Room 3 Uncertainties and Correlations of Wind Power(1)
		RPS 27 Friendship Palace Conference Room 1 Uncertainties and Correlations of Wind Power(2)	**RPS 28** Friendship Palace Conference Room 2 Uncertainties in Power Systems(1)
		RPS 29 Friendship Palace Conference Room 3 Uncertainties of Wind Power(1)	**RPS 30** Friendship Palace Conference Room 4 Uncertainties of Wind Power(2)
10:10-10:30		**Café Break**	
10:30-11:50		**RPS 31** Building 8 Meeting Room 2 Outage Data, Events and Analysis(1)	**RPS 32** Building 8 Meeting Room 3 Outage Data, Events and Analysis(2)
		RPS 33 Friendship Palace Conference Room 1 Reliability-centered Asset Management	**RPS 34** Friendship Palace Conference Room 2 Reliability-centered Maintenance
		RPS 35 Friendship Palace Conference Room 3 Risk Management and Decision-making(2)	**RPS 36** Friendship Palace Conference Room 4 State Monitoring and Application
12:00-14:00		**Lunch** Juheyuan Restaurant, Friendship Palace First Floor	
14:00-15:40		**RPS 37** Building 8 Meeting Room 2 Wind Power Forecasting(1)	**RPS 38** Building 8 Meeting Room 3 Wind Power Forecasting(2)
		RPS 39 Friendship Palace Conference Room 1 Uncertainties in Power Systems(2)	**RPS 40** Friendship Palace Conference Room 2 Applications of Probabilistic Methods
		RPS 41 Friendship Palace Conference Room 3 Reliability of DC Grids	
15:40-16:00		**Café Break**	
16:00-17:30		**Closing Session & Best Student Paper Award Announcement** Grand Building Function Room	

Time	Thursday October 20, 2016
08:00-18:00	**Technical Tour, Great Wall Tour** (Including Lunch) Gather at the Parking Lot Behind the Grand Building of the Beijing Friendship Hotel

GENERAL INFORMATION

The City of Beijing

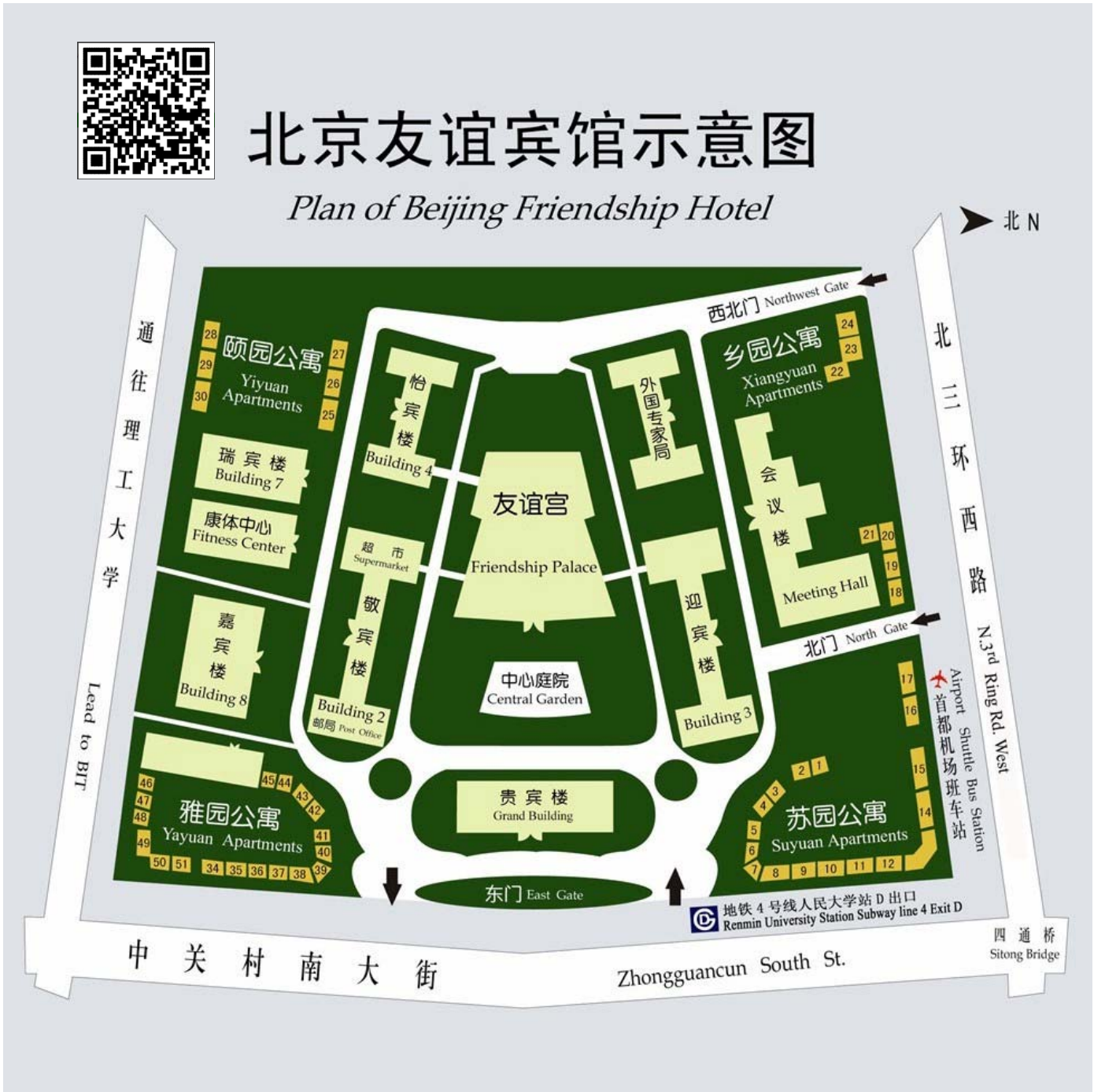
Beijing is the capital of the People's Republic of China, and the nation's political, economic and cultural center as well. It has been the heart and soul of politics and society throughout its long history and consequently there is an unequalled wealth available for you to discover. Through the years' development, Beijing has become an international cosmopolis. The metropolis is governed as a direct-controlled municipality under the national government, with 16 urban and suburban districts.

Nowadays Beijing is the second largest Chinese city by urban population after Shanghai and is the nation's political, cultural and educational center. It is home to the headquarters of most of China's largest state-owned companies, and is a major hub for the national highway, expressway, railway and high-speed rail networks. The Beijing Capital International Airport is the second busiest in the world by passenger traffic.

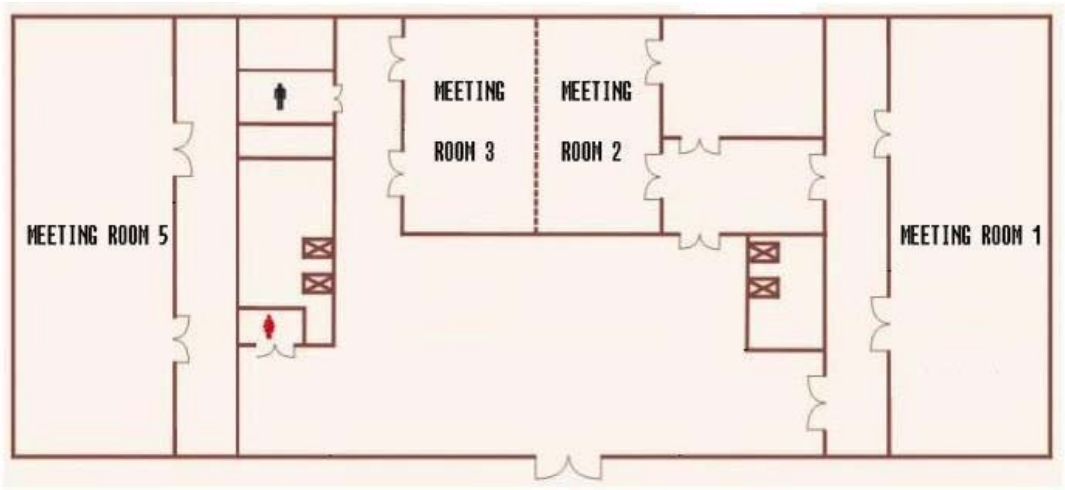
For more information about the Attractions, Shopping Malls, Local Products, Cafes, Bars of Beijing, please follow the link: http://r.visitbeijing.com.cn/ or scan the QR code:

Conference Venue

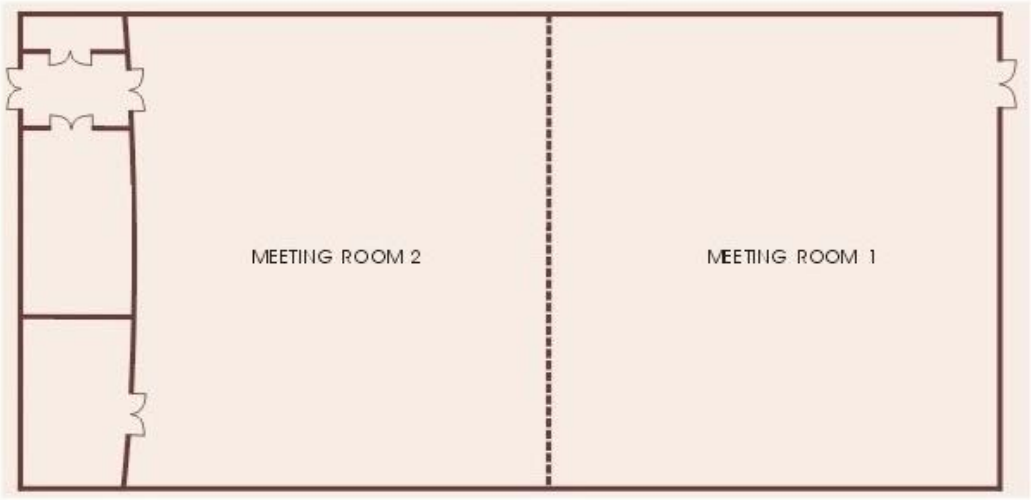
The Beijing Friendship Hotel and its plan are as follows:


北京友谊宾馆示意图
Plan of Beijing Friendship Hotel
北 N
西北门 Northwest Gate
北门 North Gate
东门 East Gate
通往理工大学
Lead to BIT
北三环西路
N.3rd Ring Rd. West
中关村南大街
Zhongguancun South St.
四通桥
Sitong Bridge
硕园公寓
Yiyuan Apartments
瑞宾楼
Building 7
康体中心
Fitness Center
嘉宾楼
Building 8
怡宾楼
Building 4
超市
Supermarket
敬宾楼
Building 2
邮局 Post Office
友谊宫
Friendship Palace
中心庭院
Central Garden
外国专家局
贵宾楼
Grand Building
乡园公寓
Xiangyuan Apartments
会议楼
Meeting Hall
迎宾楼
Building 3
雅园公寓
Yayuan Apartments
苏园公寓
Suyuan Apartments
首都机场班车站
Airport Shuttle Bus Station
地铁4号线人民大学站D出口
Renmin University Station Subway line 4 Exit D

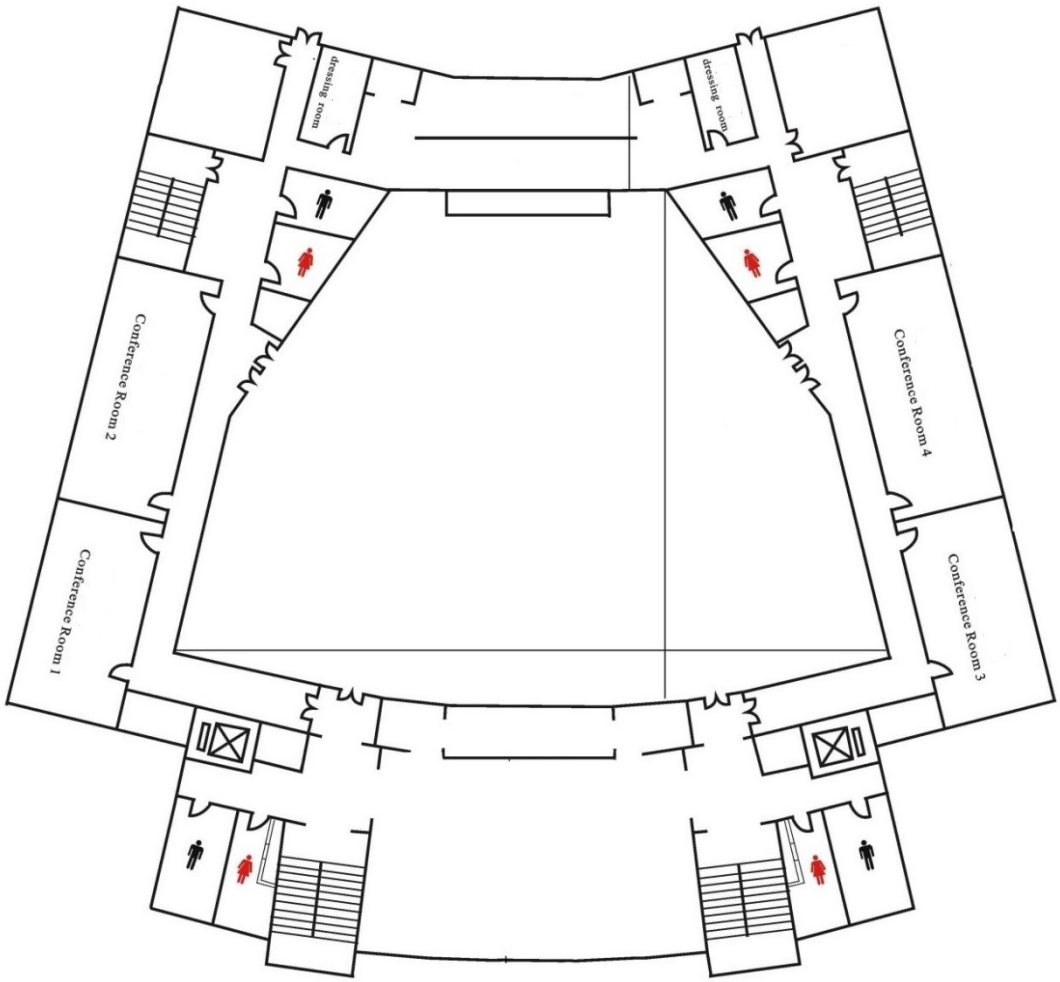
Level 1 of Building 8-Jiabin Building（嘉宾楼）



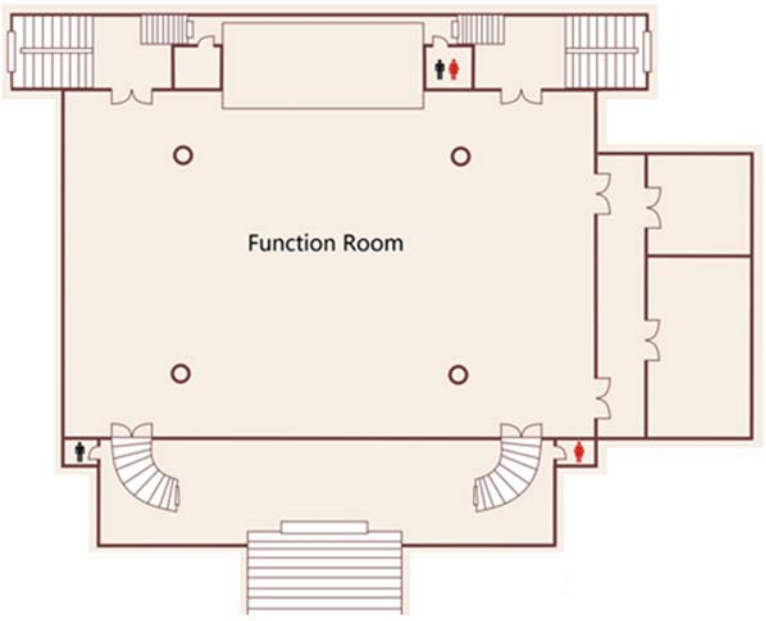
Level 2 of Building 7-Ruibin Building（瑞宾楼）



Level 2 of Friendship Palace (友谊宫)



Level 2 of Grand Building (贵宾楼)



Registration

A Registration Desk will be located at the 1st floor of the Building 2 –Jingbin Building during the following time period:

October 16th,	Sunday	07:30AM-20:00PM
October 17th,	Monday	07:30AM-17:50PM
October 18th,	Tuesday	08:00AM-18:00PM
October 19th,	Wednesday	08:00AM-17:30PM

Any inquiries about the registration, accommodation, social events etc. might be answered by approaching any of the staffs at the Registration Desk.

Tutorials

Tutorials will be held at Meeting Room 5 on the 1st floor of Building 8-Jiabin Building on 16th October.

Opening Ceremony and Plenary Session

The Plenary Session, as well as the Opening Ceremony, will be held at Meeting Room 1 and 2 on the 2nd floor of Building 7-Ruibin Building.

Panel and Invited Paper Sessions

The 2 Panel and Invited Paper Sessions in parallel will be held individually at Meeting Room 1 and 2 on the 2nd floor of Building 7-Ruibin Building.

Regular Paper Sessions

The 6 Regular Paper Sessions in parallel will be held individually at Meeting Room 2 and 3 on the 1st floor of Building 8-Jiabin Building and Conference Room 1, 2, 3 and 4 on the 2nd of Friendship Palace.

Name Badges

Delegates are required to wear their name badges at all times whilst in the conference venue and to all scientific and catered sessions, including during the technical tour and excursion on 20th October. Lost badges will be replaced at the registration desk for USD 5.

PPT Collection

Authors are encouraged to load their presentations at least **10-15minutes** before their session starts to avoid any last minute rushes and provide short bio information (two to three sentences) to the session chair so that he/she can introduce authors before the presentation. PPT will be collected by the session chair or volunteers in the session room.

Conference Hotel

The Organizing Committee has pre-reserved accommodation for participants in the following hotels.

Grand Building-Beijing Friendship Hotel (5*)	Add: 1st Zhongguancun South St., Beijing, 100873, P.R. China
Building 2-Beijing Friendship Hotel (4*)	Tel: +86-10-68498888

Cancellation or modification of hotel reservation

-Any request for cancellation or modification of your reservation during the conference must be made directly coming to the registration desk rather than to the hotel front desk.

-In case of no-show, the total amount of your full stay will be charged and no refunds will be made.

-If your plans change, please make sure that you change your reservation 48 hours ahead; otherwise, no refund will be made.

Mobile Phones

Please ensure that your mobile phone is on silent mode or turned off during all meetings you attend.

Insurance

The registration fee does not include insurance for the participants regarding accidents, sickness or loss of personal property. It is advisable to make your own arrangements in respect of health and travel insurance before leaving your countries.

Lost and Found

Any articles found should be taken to Registration Desk. Lost Property can be claimed at the same place.

Weather

Beijing has a rather dry, monsoon-influenced humid continental climate, characterized by hot, humid summers due to the East Asian monsoon, and generally cold, windy, dry winters that reflect the influence of the vast Siberian anticyclone. Autumn is the best season to visit Beijing in a year when the sky is blue; the air is crisp, mild and humid. Autumn in Beijing sees little rain, but is crisp and short. The average temperature of Autumn in Beijing is 15℃-25℃.

Transportation in Beijing

Buses are the main means of transport in Beijing. Please prepare small bills in case of no-change bus lines. It would be very crowded in rush hours at 07:00-09:00AM and 16:00-18:00PM.

The subway system in Beijing has 16 lines. The fare is CNY 3 to 9 per entry according to the mileage you travel with free transfer from one line to another. Trains run from 05:30AM in the morning until 23:30PM in the late evening. A ticket can be bought at the ticket office or at an automatic ticketing machine at each subway station. Subway stops are announced over the train's speaker system in Chinese and English. It would be very crowded in rush hours at 07:00-09:00AM and 17:00-18:30PM.


北京地铁线路图
Beijing Subway Map
图例：
Legend
地铁1号线
地铁八通线
地铁2号线
地铁4号线
地铁大兴线
地铁5号线
地铁6号线
地铁7号线
地铁8号线
地铁9号线
地铁10号线
地铁13号线
地铁14号线
地铁15号线
地铁房山线
地铁昌平线
地铁亦庄线
机场线
换乘站
北
NORTH
注：7号线双井站暂缓开通
北京地铁官方网站
http://www.bjsubway.com
地铁服务热线
社会监督电话 96165
Service Hotline

SOCIAL PROGRAM

Welcome Reception

Welcome reception for participants will be held at the 1st floor of Grand Building-Beijing Friendship Hotel on Sunday, 16th October. The reception coupon issued in your registration package is required to be presented.

Banquet Dinner

Banquet Dinner for participants will be held at the first floor of Grand Building-Beijing Friendship Hotel on Tuesday, 18th October. The dinner coupon issued in your registration package is required to be presented.

Working Lunch

Lunches will be served at the 1st floor of the Friendship Palace from 16th October to 19th October. The lunch on 16th October will only be open to the participants who register the Tutorials. The lunch coupon issued in your registration package must be presented.

Café Breaks

Morning and afternoon Café break station will be set up daily adjacent to each conference room.

Technical Tours

Technical Tour and excursion to the Great Wall will be gathered at the parking lot behind Grand building at 8:00AM on 20th October. Participants who take technical tour only, Great Wall only and both technical tour and Great Wall will take different buses. Please be attentive to the indicators in front of the bus window. All participants are encouraged to arrive **10 minutes in advance** before gathering.

We would like to sincerely thank State Grid Beijing Electrical Power Company for their generous support for Technical Tours.

Timeline

Line 1. Technical Tour and Excursion to Great Wall

8:00AM Gather at **the parking lot behind the Grand building** of the Beijing Friendship Hotel
10:00AM-12:00PM Great Wall of Badaling
12:30-14:00PM Lunch
14:00-16:00PM Yanqing Microgrid Project in Beijing
16:00-18:00PM Back to the Beijing Friendship Hotel

Line 2. Excursion to Great Wall

8:00AM Gather at **the parking lot behind the Grand building** of the Beijing Friendship Hotel
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10:00AM-12:00PM Yanqing Microgrid Project in Beijing
12:30-14:00PM Lunch
14:00-16:00PM Back to the Beijing Friendship Hotel

Optional Tours

Personalized local tours can be booked at the Concierge of Grand Building.

Official Web

More materials such as the photos on site, the list of Student Awards etc. will be updated at http://www.pmaps2016.org after the conference.

Scan QR code to get access to the official web:

Emergency Contact and Useful Phone Number

Academy:	Juan Yu	+86	13637962128
Registration:	Jing Pei	+86	18510086124
Logistic:	Joana Yi	+86	13811877290

TUTORIALS

Tutorial-I: Power System Reliability Evaluation

Date: Sunday October 16, 2016

Time: 8:45-10:10AM, 10:30AM-12:00PM

Room: Building 8 Meeting Room 5

Speaker: Dr. Roy Billinton,
Distinguished Emeritus Professor,
Electrical and Computer Engineering,
University of Saskatchewan, Canada

Content:

This part of the tutorial will briefly introduce some of the basic probability concepts used in the reliability assessment of electric power systems and then focus on the reliability evaluation of generation, transmission and distribution systems. The utilization of both analytical techniques and Monte Carlo simulation will be presented. The reliability information requirements to support both predictive and past performance assessments of load point and system reliability will be illustrated using Canadian electric power utility data. This part will also illustrate the extension of conventional reliability indices to value based reliability assessment incorporating customer interruption costs.

Presently Distinguished Emeritus Professor of Electrical and Computer Engineering, University of Saskatchewan, Canada. Author or co-author of eight books on reliability and over 975 papers on power system analysis, stability, economic system operation, and reliability. Fellow of the Institute of Electrical and Electronic Engineers (1978), Royal Society of Canada (1980), the Engineering Institute of Canada (1981), the Canadian Academy of Engineering (1999), Foreign Associate of the United States National Academy of Engineering (2007), and a Professional Engineer in the Province of Saskatchewan, Canada (1964). Recipient of the Canadian Electrical Association Distinguished Service Award (1991), IEEE Outstanding Power Engineering Educator Award (1992), IEEE Canada McNaughton Gold Medal (1994), IEEE Canada Outstanding Engineering Educator Award (2001), IEEE Charles Proteus Steinmetz Award (2008), IEEE Canada Electric Power Medal (2008).

Tutorial-II: Applications and Researches in Power System Reliability Assessment

Date: Sunday October 16, 2016

Time: 14:00-15:30PM

Room: Building 8 Meeting Room 5

Speaker: Dr. Armando Leite da Silva,
Professor at the EE Department,
PUC-Rio, Brazil

Content:

This part of the tutorial will briefly cover some advanced power system reliability concepts and their utilization in power system applications and researches. Examples of reliability assessment of generation, composite and distribution systems will be provided. The applications in areas such as operating reserve, transmission expansion planning, spare equipment, substation, probabilistic load flow, and transient stability will be reviewed. Both analytical and Monte Carlo simulation tools for evaluating reliability indices will be discussed with an emphasis on the latter, in view of large systems and renewable energy sources.

Currently Professor at the EE Department of PUC-Rio in Brazil. Areas of interest: power system analysis (static, dynamic, optimization, markets, and renewable energy); probabilistic methods applied to power systems (monitoring, operation, planning, and maintenance); stNochastic processes and Monte Carlo simulation. Received the following honors: The Sebastian Z. de Ferranti Premium Award (Power Division of the IEE/IET, UK, 1992); Fellow (IEEE, USA, 2000); PMAPS Merit Award (2010); IEEE PES Technical Committee PSACE Prize Paper Award (2011); IEEE-PES Roy Billinton Power System Reliability Award (2012); Advisory Professor of Chongqing University (2014).

Tutorial-III: Computational Intelligence, Information Theoretic Learning and Auto-encoding Applied to Probabilistic Modeling in Smart Grids and Systems with Renewables

Date: Sunday October 16, 2016

Time: 15:50-17:20PM

Room: Building 8 Meeting Room 5

Speaker: Dr. Vladimiro Miranda,
Director, the Board of INESC TEC,
Professor, University of Porto,
President, INESC P&D Brazil
Director, OCEANUS Marine Research and Innovation, University of Porto

Content:

This part of the tutorial will briefly discuss how the high penetration of renewable sources in power systems and the smart grid paradigm drive the pervasive adoption of probabilistic models, and how adaptive learning from data is becoming more important than ever. Some computational intelligence tools for solving stochastic models will be reviewed with their applications in unit commitment, reactive power planning and reliability evaluation in systems with wind power generation. This part also explains how advances in supervised learning derive from a new interpretation of cost functions in terms of information theoretic concepts. Examples of wind and solar power prediction will be presented, as well as topology estimators and state estimators from smart grid environments. The future trend towards building cognitive models and architectures for simulation and operation control will be discussed.

Presently Director on the Board of INESC TEC, Professor at the University of Porto, President of INESC P&D Brazil, Director at OCEANUS Marine Research and Innovation in the University of Porto. Areas of interest: computational intelligence applied to power systems, renewables integration, forecasting, reliability and state estimation processes in smart grid environments. Member of the Scientific Council of IRESEN of the Government of Morocco, Member of the Scientific Council of the Laboratory for Chemical and Biological Defense of the Portuguese Armed Forces, Academic Advisor of the Hong Kong Polytechnic University, China, and Invited Professor at the University of Novi Sad, Serbia. Fellow of the IEEE and the recipient of the IEEE PES Ramakumar Family Renewable Energy Excellence Award (2013).

OPENING CEREMONY AND PLENARY SESSION

October 17, 2016 Monday, 08:40-11:45AM Room: Building 7 Meeting Room 1&2

8:40-8:50AM: Welcome Speech

Professor Wenyuan Li, Chongqing University and Associate Professor Lin Cheng, Tsinghua University

8:50-9:00AM: PMAPS IS Chair's speech

Professor Roy Billinton, University of Saskatchewan

9:00-11:45AM: Plenary Session

9:00-9:45AM: **Professor Göran Andersson, Swiss Federal Institute of Technology**

Plenary Speech: *Research Challenges of the Future Electric Power System*

9:45-10:15AM: Café break

10:15-11:00AM: **Professor Xiaoxin Zhou, China Electric Power Research Institute**

Plenary Speech: *Energy Transition and Power System Evolution in China*

11:00-11:45AM: **Professor James McCalley, Iowa State University**

Plenary Speech: *Co-optimized expansion planning applications and uncertainty*

12:00PM: **Lunch**

Plenary Session

The first speech: Research Challenges of the Future Electric Power System

Date: Monday October 17, 2016

Time: 09:00-09:45AM

Room: Building 7 Meeting Room 1&2

Speaker: Professor Göran Andersson

Abstract:

During its more than 100 years of existence, the electric power system has been faced with various challenges, which had to be overcome to shape the system as we know it today. Due to an effective cooperation between the power industry and universities and other research institutions, we have today in many parts of the world a system that provides its users with high quality and reliable power at affordable prices. The list of technical, economical, and regulatory issues that have been solved is virtually endless and the continuous and close teamwork between different stakeholders has been essential in this success story. In order to tackle the future challenges it is of utmost importance that this cooperation be continued and be more interactive so that the research community can play a pivotal role in this important task.

This lecture will first give a brief historical overview of how research results have had a significant influence on the development of the electric power system. Second, the most salient challenges, according to the author, the power system is faced with will be discussed. Examples that will be presented are handling of uncertainties and risks, data management, interaction with other energy

systems, consumer behavior, various implications of technical changes, and cyber security. Many of these challenges would require new approaches, system designs and controls, system and component models, or new analytical and computational techniques to be effectively resolved.

Further, a model for the cooperation and interaction between industry and research institutions will be sketched. Even if the overall goal of all the stakeholders is the same, they have different roles to play and this must acknowledged in the set-up of the cooperative projects.

Göran Andersson obtained his M.S. (1975) and Ph.D. (1980) degrees from the University of Lund, Sweden. In 1980 he joined ASEA's, now ABB's, HVDC division in Ludvika, Sweden, and in 1986 he was appointed full professor in electric power systems at KTH (Royal Institute of Technology), Stockholm, Sweden. Since 2000 he is full professor in electric power systems at ETH Zürich (Swiss Federal Institute of Technology). His research interests include power system dynamics, control and operation, power markets, and future energy systems.

Göran Andersson is Fellow of IEEE, the Royal Swedish Academy of Sciences, the Royal Swedish Academy of Engineering Sciences, the Swiss Academy of Engineering Sciences, and foreign member of the US National Academy of Engineering. He was the recipient of the 2007 IEEE PES Outstanding Power Educator Award, the 2010 George Montefiore International Award 2010, and the 2016 IEEE PES Prabha S. Kundur Power System Dynamics and Control Award.

The second speech: Energy Transition and Power System Evolution in China

Date: Monday Octotber 17, 2016

Time: 10:15-11:00AM

Room: Building 7 Meeting Room 1&2

Speaker: Professor Xiaoxin Zhou

Abstract:

The goal of China's energy transition is to build a clean, low-carbon, safe, efficient and sustainable modern energy system by the years 2030-2050. To achieve the goals of energy transition, wind and solar power need to be highly exploited and integrated into power systems. Based on the background of energy transition, the power system in China will take two characteristics as major evolution trends: power systems with high penetration of renewable sources; power systems with high proportion of power electronic equipment.

The smart integrated energy system is an extension of smart grid, which is a new evolution trend for traditional power systems. New materials and new technologies will bring the possibility of subversive change of the power system.

In the process of the power system evolutions, new theories and technologies are needed to address the

challenges of power system operation and control.

Professor Xiaoxin Zhou graduated from the Electrical Engineering Department, Tsinghua University in 1965. Currently he is an Honorary President of China Electric Power Research Institute. He was elected a member of the Chinese Academy of Sciences in 1993 and IEEE Fellow in 1995, respectively. He is a member of Standing Committee of Chinese Society for Electrical Engineers (CSEE) and the Chief Editor of "CSEE Journal of Power and Energy Systems".

The third speech: Co-optimized Expansion Planning Applications and Uncertainty

Date: Monday October 17, 2016

Time: 11:00-11:45AM

Room: Building 7 Meeting Room 1&2

Speaker: Professor James McCalley

Abstract:

Generation expansion planning (GEP) applications have been in commercial use for many years. Transmission expansion planning (TEP) applications are a more recent development, but many research-grade versions are available. Co-optimization expansion planning (CEP) applications have only recently been developed; these select transmission and generation investments simultaneously, within a single optimization. Results indicate when, where, which technology, and how much capacity to invest. CEP applications have become of very high interest over the past 10 years as a result of dramatic changes that high renewable penetration has imposed on electric power grids. In this talk, we will describe recent CEP developments and extensions, and we will illustrate results of their use, including extension to coordinate transmission and generation investments with distributed resources at the distribution level. We will also describe more general CEP application to other infrastructures including electric and gas pipeline systems and to electric, fuel, and freight/passenger transportation systems. We will conclude this talk by describing methods of CEP formulations which handle uncertainty.

James D. McCalley received the B.S., M.S., and Ph.D. degrees from Georgia Tech in 1982, 1986, and 1992, respectively. He is an Anson Marston Distinguished Professor and the London Professor of Power Systems Engineering in the Department of Electrical and Computer Engineering at Iowa State University (ISU) where he has been employed since 1992. He was elected as an IEEE Fellow in 2003.

He was employed with the Atlanta Gas Light-Company from 1977-1982 and with Pacific Gas and Electric Company (PG&E), San Francisco, from 1985 to 1990. At PG&E, Dr. McCalley was a transmission engineer where he performed planning, design, and operating studies of the Western US interconnected power grid. He was a registered professional engineer in California.

PANEL AND INVITED PAPER SESSIONS

Panel and Invited Paper Session: P&IS 1

Monday October 17, 2016, 14:00-16:00PM

Session 1	**Probabilistic methods and tools in power systems**	Monday Oct. 17, 14:00-16:00PM
Chair	**Roy Billinton, University of Saskatchewan, Canada**	**Building 7 Meeting Room 1**

Session	***Time***	***Title***	***Panelist***	***Affiliation***
P&IS 1.1	14:00-14:30	Optimization and Decision Making for Planning and Operation of Smart Integrated Energy Systems	Qinghua Wu	South China University of Technology, China
P&IS 1.2	14:30-15:00	Energy Storage Consideration in Power System Reliability Evaluation	Rajesh Karki	University of Saskatchewan, Canada
P&IS 1.3	15:00-15:30	Asset Management of Smart Power Systems	Lina Bertling Tjernberg	Royal Institute of Technology - KTH, Sweden
P&IS 1.4	15:30-16:00	Risk Assessment of Smart Grids Considering Flexible Demand Resources	Yi Ding	Zhejiang University, China

Panel and Invited Paper Session: P&IS 2

Monday October 17, 2016, 14:00-16:00PM

Session 2	**Probabilistic applications in utilities**	Monday Oct. 17, 14:00-16:00PM
Chair	**Armando Leite da Silva, Catholic University of Rio de Janeiro, Brazil**	**Building 7 Meeting Room 2**

Session	***Time***	***Title***	***Panelist***	***Affiliation***
P&IS 2.1	14:00-14:30	Probabilistic Applications in Utilities with Specific Focus on the Western US	Milorad Papic	Idaho Power, USA
P&IS 2.2	14:30-15:00	Probabilistic Methods for Uncertainty Issues in Power System Operation	Jizhong Zhu	China Southern Power Grid, China
P&IS 2.3	15:00-15:30	Capacity Value of Solar Power	Chris J Dent	University of Edinburgh, UK
P&IS 2.4	15:30-16:00	Risk Pruning under Islanding Conditions Using Wind-Hydro Generation Coordination	Wijarn Wangdee	King Mongkut's University of Technology North Bangkok (KMUTNB), Thailand

Panel and Invited Paper Session: P&IS 3

Monday October 17, 2016, 16:20-17:50PM

Session 3	**Cyber-physical risk of power systems**		Monday Oct. 17, 16:20-17:50PM	
Chair	**Qinghua Wu, South China University of Technology, China**		**Building 7 Meeting Room 1**	
Session	***Time***	***Title***	***Panelist***	***Affiliation***
P&IS 3.1	16:20-16:50	Developing a Benchmark Test System for Electric Power Grid Cyber-Physical Reliability Studies	Chanan Singh	Texas A&M University, USA
P&IS 3.2	16:50-17:20	A UHV Grid Security and Stability Defense System Considering the Risk of Communication System	Ming Ni	NARI Group Corporation, China
P&IS 3.3	17:20-17:50	Advanced System Restoration Planning and Its Implication to Cyber-physical Resilience of Next Generation Power Grid	John N. Jiang	The University of Oklahoma, USA

Panel and Invited Paper Session: P&IS 4

Monday October 17, 2016, 16:20-17:50PM

Session 4	**Big data applications in power systems**		Monday Oct. 17, 16:20-17:50PM	
Chair	**James McCalley, Iowa State University, USA**		**Building 7 Meeting Room 2**	
Session	***Time***	***Title***	***Panelist***	***Affiliation***
P&IS 4.1	16:20-16:50	Comparing Two Model Selection Frameworks for Probabilistic Load Forecasting	Tao Hong	University of North Carolina at Charlotte, USA
P&IS 4.2	16:50-17:20	Big Data Analytics in Large Scale Power System Economic Planning	Yingzhong Gu	General Electric, USA
P&IS 4.3	17:20-17:50	Probabilistic Modeling of Renewable Energy Based On Spark Platform	Juan Yu	Chongqing University, China

REGULAR PAPER SESSIONS

Regular Paper Sessions: RPS 1 - RPS 6

Tuesday October 18, 2016, 08:30-10:10AM

Session 1	**Forecast techniques in power systems**	Tuesday Oct. 18, 08:30-10:10AM
Chair	**Jizhong Zhu, China Southern Power Grid, China**	**Building 8 Meeting Room 2**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 1.1	41	08:30-08:50	Enhanced Computation of Ultra-Short-Term Prediction Intervals of PV AC Active Power	Enrica Scolari, Dimitri Torregrossa, Jean-Yves Le Boudec, Mario Paolone
RPS 1.2	64	08:50-09:10	Approximate Active Power Distributions for Standard Household Loads	Robert Brandalik, Dominik Waeresch, Wolfram H. Wellssow
RPS 1.3	258	09:10-09:30	Prediction of Availability and Charging Rate at Charging Stations for Electric Vehicles	Can Bikcora, Nazir Refa, Lennart Verheijen, Siep Weiland
RPS 1.4	267	09:30-09:50	Prediction of Current in a Substation in order to Schedule Thermography	Per Westerlund, Patrik Hilber, Tommie Lindquist
RPS 1.5	278	09:50-10:10	A Stochastic Optimal Model of Micro Energy Internet Contains Rooftop PV and CCHP System	Lin Cheng, Chen Liu, Qiang Wu, Song Gao

Session 2	**Cascading failures in power systems**	Tuesday Oct. 18, 08:30-10:10AM
Chair	**Xuemin Zhang, Tsinghua University, China**	**Building 8 Meeting Room 3**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 2.1	49	08:30-08:50	Comparing a Transmission Planning Study of Cascading with Historical Line Outage Data	Milorad Papic, Ian Dobson
RPS 2.2	70	08:50-09:10	Analysis of Cascading Failure Considering Load-shedding Strategy and Failure Correlation	Dajun Si, Qiming Sun, Libao Shi, Yingchun Qian, Wen Qian
RPS 2.3	199	09:10-09:30	Review on Power System Cascading Failure Theories and Studies	Xiaohui Ye, Wuzhi Zhong, Xinli Song, Guoyang Wu, Tao Liu, Zhida Su
RPS 2.4	254	09:30-09:50	Identification of Critical Line-Generation Combinations for Hypothesized Joint Line-Generation Attacks	Ming Wang, Yingmeng Xiang, Lingfeng Wang, Jie Jiang, Ruosong Xiao, Kaigui Xie
RPS 2.5	255	09:50-10:10	A Resilient Power System Operation Strategy Considering Presumed Attacks	Yingmeng Xiang, Lingfeng Wang, Nian Liu, Ruosong Xiao, Kaigui Xie

Session 3	**Stochastic optimization and simulation(1)**	Tuesday Oct. 18, 08:30-10:10AM
Chair	**Bagen Bagen, Manitoba Hydro, Canada**	**Friendship Palace Conference Room 1**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 3.1	53	08:30-08:50	Stochastic Day-Ahead Generation Scheduling with Pumped-Storage Stations and Wind Power Integrated	J. H. Zheng, X. Y. Quan, Z. X. Jing, Q. H. Wu
RPS 3.2	80	08:50-09:10	Valuation of Stored Energy in Dynamic Optimal Power Flow of Distribution Systems with Energy Storage	Iver Bakken Sperstad, Arild Helseth, Magnus Korpås
RPS 3.3	121	09:10-09:30	A Novel Method for Energy Storage Sizing Based on Time and Frequency Domain Analysis	Liting Tian, Jianbo Guo, Lin Cheng
RPS 3.4	198	09:30-09:50	Online Security Assessment with Load and Renewable Generation Uncertainty: the iTesla Project Approach	Maria Helena Vasconcelos, Leonel Carvalho, José Meirinhos, N. Omont, P. Gambier-Morel, G. Jamgotchian, D. Cirio, E. Ciapessoni, A. Pitto, I. Konstantelos, G. Strbac, M. Ferraro, C. Biasuzzi
RPS 3.5	250	09:50-10:10	A Dynamic Programming-Based Heuristic Approach for Optimal Transmission Switching Problem With N-1 Reliability Criterion	Farzaneh Pourahmadi, Mohammad Jooshaki, Seyed Hamid Hosseini

Session 4	**Stability of power systems**	Tuesday Oct. 18, 08:30-10:10AM
Chair	**Pierre Pinson, Technical University of Denmark, Denmark**	**Friendship Palace Conference Room 2**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 4.1	16	08:30-08:50	Literature Review of Power System Stochastic Stability	Hao Jiang, Hui Liu, Linlin Wu, Haixiang Xu
RPS 4.2	29	08:50-09:10	Stochastic Small Disturbance Stability Analysis of Multi-machine System Based on Energy Function	Rui Wang, Jie Wang, Xiao Mi
RPS 4.3	45	09:10-09:30	Solutions to Probabilistic Analysis of Voltage Stability in Power Systems with Wind Farms Using Advanced Unscented Transformation	Haibo Bao, Hua Wei, Xiaoxuan Guo
RPS 4.4	164	09:30-09:50	Quasi Hamilton System Stochastic Averaging and EEAC Combined Transient Stability Analysis Method	Haiqiang Zhou, Jizhu Guo, Ping Ju
RPS 4.5	192	09:50-10:10	The Stability Analysis and New Torque Control Strategy of Direct-Driven PMSG Wind Turbines	Jun Lin, Feihang Zhou, Guangyi Wang

Session 5	**Power system operations**	Tuesday Oct. 18, 08:30-10:10AM
Chair	**Yi Ding, Zhejiang University, China**	**Friendship Palace Conference Room 3**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 5.1	40	08:30-08:50	Spinning Reserve Assessment via Quasi-Sequential Monte Carlo Simulation with Renewable Sources	Armando Leite da Silva, Jose Filho da Costa Castro, Reinaldo Gonzalez-Fernandez
RPS 5.2	75	08:50-09:10	On Improving Data/Models on Corrective Control Failures for Use in Probabilistic Reliability Management	Vijay Venu Vadlamudi, Camille Hamon, Oddbjørn Gjerde, Samuel Perkin, Gerd Kjølle, Samuel Perkin
RPS 5.3	78	09:10-09:30	Impact of Increased Uncertainty in Power Systems on Performance of Short Term Reliability Management	Evelyn Heylen, Geert Deconinck, Dirk Van Hertem
RPS 5.4	237	09:30-09:50	Application of Voltage Sensitivity Analysis in a Probabilistic Context for Characterizing Low Voltage Network Operation	Vasiliki Klonari, Bashir Bakhshideh Zad, Jacques Lobry, François Vallee
RPS 5.5	256	09:50-10:10	Using VaR and CVaR Techniques to calculate the Long-term Operational Reserve	Leonardo Bremermann, Mauro Rosa, Leonel Carvalho, Pablo Galvis, Caio Nakasone, Fernando Santos

Session 6	**Power system optimization**	Tuesday Oct. 18, 08:30-10:10AM
Chair	**Jaeseok Choi, Geongsang National University, South Korea**	**Friendship Palace Conference Room 4**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 6.1	214	08:30-08:50	Impact of Network Topology Optimization on Power System Reliability	Yingmeng Xiang, Lingfeng Wang, Ruosong Xiao, Kaigui Xie
RPS 6.2	166	08:50-09:10	DATP-based Sequential Optimization and Reliability Assessment for RBDO	Chen Jiang, Haobo Qiu, Xiaoke Li, Ning Ma, Liang Gao, Xiwen Cai
RPS 6.3	179	09:10-09:30	Reliability and Efficiency-based Energy Storage Sizing From the Aspect of System Frequency	Chen Liang, Peng Wang, Xiaoqing Han, Wenping Qin, Yanbing Jia
RPS 6.4	137	09:30-09:50	Applying High Performance Computing to Probabilistic Convex Optimal Power Flow	Zhao Yuan, Mohammad Reza Hesamzadeh, Yue Cui, Lina Bertling Tjernberg
RPS 6.5	239	09:50-10:10	Reactive Power Adequacy Assessment of Composite Power System Based on Interior Point Method and Genetic Algorithm	Fan Chen, Haitao Liu, Jun Li, Zheng Huang

Regular Paper Sessions: RPS 7 - RPS 12

Tuesday October 18, 2016, 10:30-11:50AM

Session 7	**Identification analysis**			Tuesday Oct. 18, 10:30-11:50AM
Chair	**Göran Andersson, ETHZ, Switzerland**			**Building 8 Meeting Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 7.1	20	10:30-10:50	Determining A Critical Contingency Set Using Probabilistic Performance Indexes	Jun Zhong, Hailei He, Bo Hu, Qinyong Zhou, Wenyuan Li
RPS 7.2	130	10:50-11:10	Reliability Evaluation Based on Equivalent Method of Sensitivity Consistency and Component Particularity Representation	Shicong Deng, Bin Zhang, Juan Yu, Wei Lin, Wenyuan Li, Xuan Liu
RPS 7.3	150	11:10-11:30	Probabilistic-Based Identification of Coherent Generators	Oscar Gomez, George Anders, Carlos Zapata
RPS 7.4	189	11:30-11:50	Overhead Line Weak Point Mechanical Analysis Based on Markov Chain Method.	Anna Mutule, Ervin Grebesh, Irina Oleinikova, Artjoms Obushevs

Session 8	**Probabilistic assessment in power market**			Tuesday Oct. 18, 10:30-11:50AM
Chair	**Alfredo Testa, The Second University of Naples, Italy**			**Building 8 Meeting Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 8.1	47	10:30-10:50	Population Dynamics for Renewables in Electricity Markets: A Minority Game View	Athanasios Papakonstantinou, Pierre Pinson
RPS 8.2	190	10:50-11:10	Long-Term Spanish Electricity Market Price Forecasting with Cointegration and VEC Models	Rodrigo A. de Marcos, Javier Reneses, Antonio Bello
RPS 8.3	191	11:10-11:30	An Agent Based Model of a Frequency Activated Electricity Reserve Market	Markus Löschenbrand, Magnus Korpås
RPS 8.4	245	11:30-11:50	Risk-Based Penalty Price Determination Procedure for Transmission Constraint Relaxations	Ahmed Salloum, Yousef Al-Abdullah, Kory Hedman, Vijay Vittal

Session 9	**Stochastic optimization and simulation(2)**	Tuesday Oct. 18, 10:30-11:50AM
Chair	**Lina Bertling Tjernberg, KTH, Sweden**	**Friendship Palace Conference Room 1**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 9.1	140	10:30-10:50	Spectrum Analysis Method of Residual Current Based on Hilbert-Huang Transform	Jinli Wang, Yongmei Liu, Li Wang, Songhuai Du, Juan Su, Yating Cai, Tingting Fan, Haiou Guan
RPS 9.2	201	10:50-11:10	The Anomalous Data Identification Study of Reactive Power Optimization System Based on Big Data	Wanxing Sheng, keyan Liu, Huanna Niu, Yuzhu Wang, Jingxiang Zhao
RPS 9.3	202	11:10-11:30	Stochastic Generator Availability Modeling on Very Large Transmission Network Systems	Brandon Heath, John Lawhorn
RPS 9.4	227	11:30-11:50	Optimal Coupling of Heat and Electricity Systems: A Stochastic Hierarchical Approach	Lesia Mitridati, Pierre Pinson

Session 10	**Uncertainties of solar power**	Tuesday Oct. 18, 10:30-11:50AM
Chair	**Milorad Papic, Idaho Power, United States**	**Friendship Palace Conference Room 2**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 10.1	51	10:30-10:50	Unit Commitment Risk Evaluation of Power Systems with PV and Energy Storage	Wei Jia Tay, Qian Zhao, Ashwin M Khambadkone
RPS 10.2	83	10:50-11:10	A Study on Several Hours Ahead Forecasting of Spatial Average Irradiance using NWP model and Satellite Infrared Image	Takeyoshi Kato, Yusuke Manabe, Toshihisa Funabashi, Keita Yoshiura, Muneaki Kurimoto, Yasuo Suzuoki
RPS 10.3	84	11:10-11:30	Modeling Impacts of PM 2.5 Concentration on PV Power Outputs	Chi Zhang, Wenyuan Li, Juan Yu, Ruilin Xu
RPS 10.4	85	11:30-11:50	A Hybrid Probabilistic Assessment Using Different Renewable Penetration Scenarios in the North American Bulk Power System	Noha Abdel-Karim, David Calderon, Thomas Coleman, John Moura

Session 11	**Equipment and system failures(1)**	Tuesday Oct. 18, 10:30-11:50AM
Chair	**Zhaohong Bie, XI'AN JIAOTONG University, China**	**Friendship Palace Conference Room 3**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 11.1	21	10:30-10:50	A Performance and Maintenance Evaluation Framework for Wind Turbines	Peyman Mazidi, Mian Du, Lina Bertling Tjernberg, Miguel A. Sanz Bobi
RPS 11.2	38	10:50-11:10	Improved Analytic Model to Detect Hidden Failure of Protection Relays	Yuan Tian, Yan Hu, Jia Liu
RPS 11.3	181	11:10-11:30	Failure Rate Estimation of Power Transformers Using Inspection Data	Ehsan Abbasi, Om P. Malik
RPS 11.4	260	11:30-11:50	Probabilistic Assessment of PMU Integrity for Planning of Periodic Maintenance and Testing	Tamara Becejac, Payman Dehghanian, Mladen Kezunovic

Session 12	**Equipment and system failures(2)**	Tuesday Oct. 18, 10:30-11:50AM
Chair	**Bo Hu, Chongqing University, China**	**Friendship Palace Conference Room 4**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 12.1	48	10:30-10:50	Hybrid Entropy Evaluation of Equipment Severity to Voltage Sags	Jun Xiong, Wenliang Liu, Yi Zhang, Yan Lin, Danyue Wu
RPS 12.2	59	10:50-11:10	A Review and Discussion of Failure Rate Heterogeneity in Power System Reliability Assessment	Jan Henning Jürgensen, Lars Nordström, Patrik Hilber
RPS 12.3	253	11:10-11:30	Wind Farm Analysis in terms of Turkish Grid Code	Mustafa Demirol, Ramazan Caglar, Tuğba N. Demirol
RPS 12.4	269	11:30-11:50	Introducing Distributed Learning Approaches in Wind Power Forecasting	Pierre Pinson

Regular Paper Sessions: RPS 13 - RPS 18

Tuesday October 18, 2016, 14:00-15:40PM

Session 13	**Power system planning considering Reliability**			Tuesday Oct. 18, 14:00-15:40PM
Chair	**Mauro Rosa, Federal University of Santa Catarina, Brazil**			**Building 8 Meeting Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 13.1	19	14:00-14:20	Evaluation of Transmission Network Reinforcements in an Automated Network Planning Process	Helge Pluntke, Marco Weisenstein, Wolfram Wellssow
RPS 13.2	39	14:20-14:40	Transmission Expansion Planning Based on Relaxed N-1 Criteria and Reliability Indices	Armando Leite da Silva, Muriell de Rodrigues e Freire, Fernando Aparecido de Assis, Luiz Antonio da Fonseca Manso
RPS 13.3	74	14:40-15:00	Transmission Network Expansion Planning With Stochastic Multivariate Load and Wind Modeling	Mingyang Sun, Ioannis Konstantelos, Goran Strbac
RPS 13.4	229	15:00-15:20	Discrete Forecast Error Scenarios Methodology for Grid Reliability Assessment in Short-term Planning	Gamze Dogan, Pierre-Etienne Labeau, Jean-Claude Maun, Jonathan Sprooten, Manuel Galvez, Kristof Sleurs
RPS 13.5	263	15:20-15:40	Reliability Evaluation in Power Distribution System Planning Studies	Saeed Heidari, Mahmud Fotuhi-Firuzabad

Session 14	**Probabilistic analysis in demand side management**			Tuesday Oct. 18, 14:00-15:40PM
Chair	**Chris Dent, Edinburgh University, United Kingdom**			**Building 8 Meeting Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 14.1	60	14:00-14:20	The Research of Wind Power Accommodation Considering the Prediction Error of Wind Power	Peng Zhang, Chunyan Li, Qian Zhang
RPS 14.2	88	14:20-14:40	Reliability Evaluation of Medium Voltage Distribution Network with Private Electric Vehicle	Guanglin Cai, Yong Lin, Jiajia Huan, Ya Chen, Bo Hu, Bo Li
RPS 14.3	158	14:40-15:00	Time-of-use Pricing in Retail Electricity Market: Step Tariff vs. Usage-based Schemes	Yanglin Zhou, Feng Gao, Song Ci, Yang Yang
RPS 14.4	173	15:00-15:20	Smart Meter Data Taxonomy for Demand Side Management in Smart Grids	Zafar Khan, Dilan Jayaweera, Hasan Gunduz
RPS 14.5	221	15:20-15:40	Probabilistic Assessment of a Distribution Tariff Scheme for Incentivizing Demand Side Management in the Small Energy Usage Sector	Vasiliki Klonari, Aimilios Orfanos, Jacques Lobry, Francois Vallee

Session 15	**Probabilistic power flow and applications**		Tuesday Oct. 18, 14:00-15:40PM
Chair	**Haiwang Zhong, Tsinghua University, China**		**Friendship Palace Conference Room 1**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 15.1	22	14:00-14:20	Probabilistic Load Flow: a Business Park Analysis, Utilizing Real World Meter Data	Alexander Melhorn, Aleksandar Dimitrovski, Andrew Keane
RPS 15.2	82	14:20-14:40	Benefits of Coordinated Control Reserve Activation and Grid Management – a Probabilistic Load Flow Analysis	Marie-Louise Kloubert, Johannes Schwippe, Joachim Bertsch, Simeon Hagspiel, Stefan Lorenzcik, Felix Höffler, Christian Rehtanz
RPS 15.3	185	14:40-15:00	Power System Risk Assessment Method Based on Dynamic Power Flow	Xiaohui Ye, Wuzhi Zhong, Xinli Song, Lin Cheng
RPS 15.4	218	15:00-15:20	Probabilistic Power Flow Considering Variable Bandwidth Kernel Density Estimation for Traction Substation Loads of High-speed Railways	Yiming Li, Yan Sun, Chunhao Lu, Qingqing Liang
RPS 15.5	232	15:20-15:40	Effects of Uncertainties in Frequency Regulations on Probabilistic Power Flow Analysis	Lan Luo, Xia Zhao, Xinyi Li, Wei Yan, Guoping Liu, Ping Zhou, Lili Wen

Session 16	**Reliability of transmission systems**		Tuesday Oct. 18, 14:00-15:40PM
Chair	**Ming Ni, NARI Group Corporation, China**		**Friendship Palace Conference Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 16.1	141	14:00-14:20	Composite Generation and Transmission System Reliability Assessment Using Impact Increment-based State Enumeration Method	Kai Hou, Hongjie Jia, Xiaodan Yu, Yawen Li, Chang Xie, Jianfeng Yan
RPS 16.2	154	14:20-14:40	Optimal Selection of High Voltage Transmission Connected to Island Systems	Xiaoxiao Li, Xin Zhang, Yunting Song, Wei Tang, Yinshun Wang, Jingjing Wang, Xiaofei Hu, Cheng Yang
RPS 16.3	182	14:40-15:00	Reliability Evaluation of Transmission System Based on Vulnerability Analysis	Yanbing Jia, Haidan He, Peng Wang, Xiaoqing Han
RPS 16.4	195	15:00-15:20	Reliability Assessment of Multiple-Voltage Regional Transmission and Distribution System Considering Substation Interior Failure	Tewei Xu, Zongxiang Lu, Yichao Huang, Ruanming Huang, Aili Pang
RPS 16.5	252	15:20-15:40	Bulk Power System Reliability Evaluation Considering Optimal Transmission Switching and Dynamic Line Thermal Rating	Ruosong Xiao, Yingmeng Xiang, Lingfeng Wang, Kaigui Xie

Session 17	**Reliability assessment of smart grids(1)**	Tuesday Oct. 18, 14:00-15:40PM
Chair	**Joydeep Mitra, Michigan State University, United States**	**Friendship Palace Conference Room 3**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 17.1	1	14:00-14:20	Framework for System Analyses of Smart Grid Solutions with examples from the Gotland Case	Carl Johan Wallnerström, Lina Bertling Tjernberg, Patrik Hilber, Jan Henning Jürgensen
RPS 17.2	112	14:20-14:40	Reliability Evaluation of Electrical Collector System of Wind Farm Based on Sequential Monte Carlo	Lili Wen, Manli Wang, Ping Zhou, Qian Zhou, Bo Hu, Yinghao Ma, Yun Xia, Ruosong Xiao, Bo Li
RPS 17.3	147	14:40-15:00	A Multi-state Model for the Adequacy Assessment of an Autonomous Microgrid Based on Universal Generating Function	Sheng Xu, Wei Tang, Tao Yan, Yue Wang, Xianliang Zhang
RPS 17.4	159	15:00-15:20	Impact of Car Arrival/Departure Patterns on EV Parking Lot Capacity	Sitki Guner, Aydogan Ozdemir, Gorkem Serbes
RPS 17.5	204	15:20-15:40	Supply Interruptions and Voltage Dips Assessment of Automated Distribution Systems	Manuel Chiumarulo, Sasa Z. Djokic, Roberto Langella, Alfredo Testa, Alfonso Turco

Session 18	**Reliability evaluation of distribution systems and micro grids**	Tuesday Oct. 18, 14:00-15:40PM
Chair	**Brandon Heath, MISO, United States**	**Friendship Palace Conference Room 4**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 18.1	13	14:00-14:20	Simplified Reliability Evaluation formulae for Overhead Medium Voltage Distribution Networks	Lingyun Wan, Ying Zhang, Tingting Wei, Yixi Liao, Qing Zhou, Lei Xia, Zhuding Wang, Fengying Tang
RPS 18.2	52	14:20-14:40	Wind-solar Micro Grid Reliability Evaluation Based on Sequential Monte Carlo	Zhen Liu, Wenli Liu, Gaocan Su, He-Junk Yang, Gang Hu
RPS 18.3	55	14:40-15:00	Two-stage Stochastic Programming Based Model Predictive Control Strategy for Microgrid Energy Management under Uncertainties	Zhongwen Li, Chuanzhi Zang, Peng Zeng, Haibin Yu, Hepeng Li
RPS 18.4	223	15:00-15:20	A Multistage MILP-Based Model for Integration of Remote Control Switch into Distribution Networks	Milad Izadi, Mohammad Farajollahi, Amir Safdarian, Mahmud Fotuhi-Firuzabad
RPS 18.5	265	15:20-15:40	Developing a Multi-Objective Framework for Planning Studies of Modern Distribution Networks	Seyed Ahmad Haji Seyed Olia, Mohammad Jooshaki, Moein Moeini-Aghtaie, Mahmud Fotuhi-Firuzabad

Regular Paper Sessions: RPS 19 - RPS 24

Tuesday October 18, 2016, 16:00-17:20PM

Session 19	**Reliability assessment of smart grids(2)**			Tuesday Oct. 18, 16:00-17:20PM
Chair	**George Anders, Lodz University of Technology, Poland**			**Building 8 Meeting Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 19.1	28	16:00-16:20	A Smart Grid Metrics Assessment of Distribution Automation for Reliability Improvement	Han Rui, Wolfram H. Wellssow
RPS 19.2	133	16:20-16:40	Studying the Impacts of Incorporating Energy Storage Devices into an Aggregated Probabilistic Model of a Virtual Power Plant	Arijit Bagchi, Lalit Goel, Peng Wang
RPS 19.3	217	16:40-17:00	Reliability Evaluation of Active Distribution Systems Considering Energy Storage and Real-Time Electricity Pricing	Haodi Li, Lingfeng Wang, Yingmeng Xiang, Jun Tan, Ruosong Xiao, Kaigui Xie, Yun Xia
RPS 19.4	220	17:00-17:20	A New Approach for Frequency Based Short-term Reliability for a Power System	Kofi Afrifa Agyeman, Sekyung Han, Ryota Umezawa

Session 20	**Reliability techniques for power systems**			Tuesday Oct. 18, 16:00-17:20PM
Chair	**John N. Jiang, The University of Oklahoma, United States**			**Building 8 Meeting Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 20.1	15	16:00-16:20	The Probabilistic Approach to Determine the Reliability of Synchrophasor-based Damping Controllers	Anupama Konara, Udaya Annakkage, Bagen Bagen
RPS 20.2	61	16:20-16:40	Research on Reliability Evaluation Method of Catenary of High Speed Railway Considering Weather Condition	Zhen Wang, Ding Feng, Sheng Lin, Zhengyou He
RPS 20.3	174	16:40-17:00	A Three-stage CE-IS Monte Carlo Algorithm for Highly Reliable Composite System Reliability Evaluation Based on Screening Method	Chao Yan, Giambattista Luca Lucarelli, Zhaohong Bie, Ding Tao, Gengfeng Li
RPS 20.4	226	17:00-17:20	Uncertainty Quantification in Power System Reliability Using a Bayesian Framework	Meng Xu, Chris J Dent, Amy Wilson

Session 21	**Risk and reliability of power systems**			Tuesday Oct. 18, 16:00-17:20PM
Chair	**Fei Ni, Eindhoven University of Technology, Netherlands**			**Friendship Palace Conference Room 1**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 21.1	120	16:00-16:20	Reliability Evaluation of the Grid-connected Micro-grid Considering Demand Response	Ping Zhou, Ziyuan Chen, Hongqin Yang, Lili Wen, Yin Liu, Bo Hu, Yinghao Ma, Yun Xia, Ruosong Xiao, Bo Li
RPS 21.2	180	16:20-16:40	Fatigue Reliability Analysis of Wind Turbines Shafts Caused by Sub-Synchronous Oscillations During Power System Fault	Kuanyin Tian, Peng Wang, Wenping Qin, Xiaoqing Han, Yanbing Jia, Chen Liang
RPS 21.3	233	16:40-17:00	Impacts of Transient Instability on Power System Reliability	Mohammed Benidris, Joydeep Mitra, Chanan Singh
RPS 21.4	242	17:00-17:20	Relation Formulation between Daily and Hourly Load Curve Based Loss of Load Expectation Indices	Yeonchan Lee, Duy-Phuong N. Do, Ungjin Oh, Jaeseok Choi, Junmin Cha, Hongseok Choi, Dong-hoon Jeon

Session 22	**Risk assessment and warning**			Tuesday Oct. 18, 16:00-17:20PM
Chair	**Amir Safdarian, Sharif University of Technology, Iran**			**Friendship Palace Conference Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 22.1	134	16:00-16:20	Risk Measurement and Forewarning of Power Blackouts Based on Entropy Theory	Na Cao, Shuangshuang Cao, Qun Yu, Qing He
RPS 22.2	167	16:20-16:40	Power Network Accidents Risk Assessment Based on Topology Structure	Yunting Song, Wenfei Liu, Gaoqiang Qu, Xin Zhang, Yinshun Wang, Zongchuan Zhou, Xiaojing Dong, Lijun Zhao, Ai Wang
RPS 22.3	235	16:40-17:00	Evaluation of Long-term Stability Considering Secondary Contingency Scenarios	Duy-Phuong N. Do, Ungjin Oh, Yeonchan Lee, Jaeseok Choi, Trung-Tinh Tran
RPS 22.4	142	17:00-17:20	Research on Online Monitoring and State Diagnosis of Battery for Distribution Automation	Zhichu YANG, Yu SHEN, Fan YANG, Zilin WAN, Jun ZHANG, Dongxu WANG, Wei CAI

Session 23	**Risk management and decision-making(1)**	Tuesday Oct. 18, 16:00-17:20PM
Chair	**Ramazan Caglar, Istanbul Technical University, Turkey**	**Friendship Palace Conference Room 3**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 23.1	79	16:00-16:20	Near Real-life Pilot Testing of Real-time Probabilistic Reliability Assessments	Samuel Perkin, Ragnar Kristjansson, Hlynur Stefansson, Gudjon Bjornsson, Iris Baldursdottir, Magni Palsson, Efthymios Karangelos, Louis Wehenkel, Pall Jensson
RPS 23.2	168	16:20-16:40	Day-ahead Generation Schedule Model with Demand Response Considering the Secure and Economic Risks of Wind Power	Jian Wang, Zongxiang Lu, Ying Qiao, Guiping Zhu
RPS 23.3	177	16:40-17:00	Application of Time-Limited Ratings to Underground Cables to Enable Life Extension of Network Assets	David Clements, Pierluigi Mancarella, Richard Ash
RPS 23.4	176	17:00-17:20	Setting the Maximum Import Net Transfer Capacity under Extreme RES Integration Scenarios	Manuel Matos, Ricardo Bessa, Carla Gonçalves, Laura Cavalcante, Nélio Machado, Paulo Marques, Fernando Matos, Vladimiro Miranda

Session 24	**Load forecasting**	Tuesday Oct. 18, 16:00-17:20PM
Chair	**Weilin Li, Northwestern Polytechnical University, China**	**Friendship Palace Conference Room 4**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 24.1	184	16:00-16:20	Evaluating the Spatial Correlations of Multi-Area Load Forecasting Errors	Jiangnan Cheng, Ning Zhang, Yi Wang, Chongqing Kang, Yuekai Tan, Zhijian Zeng, Min Luo
RPS 24.2	216	16:20-16:40	An Optimum Regression Approach for Analyzing Weather Influence on the Energy Consumption	Qi Zeng, Ning Zhang, Yi Wang, Yuxiao Liu, Chongqing Kang, Zhijian Zeng, Wei Yang, Min Luo
RPS 24.3	222	16:40-17:00	Volatility in Electrical Load Forecasting for Long-term Horizon – An ARIMA-GARCH Approach	Swasti R. Khuntia, Jose L. Rueda Torres, Mart A.M.M van der Meijden
RPS 24.4	262	17:00-17:20	Probabilistic Modeling of Nodal Electric Vehicle Load due to Fast Charging Stations	Difei Tang, Peng Wang, Qiuwei Wu

Regular Paper Sessions: RPS 25 - RPS 30

Wednesday October 19, 2016, 08:30-10:10AM

Session 25	**Correlations in power systems**			Wednesday Oct. 19, 08:30-10:10AM
Chair	**Zongxiang Lu, Tsinghua University, China**			**Building 8 Meeting Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 25.1	44	08:30-08:50	The Analysis of Independence of Wind Speed Based on the Probability of Run-length	Mao Yang, Jian Du
RPS 25.2	50	08:50-09:10	Estimation of the Probability Density Function of Renewable Power Production using a Hybrid Method of Minimum Frequency and Maximum Entropy	Dan Li, Wei Yan, Wenyuan Li, Tao Chen
RPS 25.3	161	09:10-09:30	Impact of Spatio-Temporally Correlated Wind Generation on the Interdependent Operations of Gas and Electric Networks	Max Csef, Andrea Antenucci, Giovanni Sansavini
RPS 25.4	171	09:30-09:50	Probabilistic Static Voltage Stability Analysis Considering the Correlation of Wind Power	Han Wang, Xiaoyuan Xu, Zheng Yan, Zenghui Yang, Nan Feng, Yong Cui
RPS 25.5	277	09:50-10:10	A Two-stage Wind Speed Model for Multiple Wind Farms Considering Autocorrelations and Cross-correlations	Kaigui Xie, Shuwei Miao, Yun Xia, Yinghao Ma, Yanlin Li

Session 26	**Uncertainties and correlations of wind power(1)**			Wednesday Oct. 19, 08:30-09:50AM
Chair	**Qixin Chen, Tsinghua University, China**			**Building 8 Meeting Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 26.1	211	08:30-08:50	Application of Non-Intrusive Polynomial Chaos Expansion in Probabilistic Power Flow with Truncated Random Variables	Fei Ni, Phuong Nguyen, Sjef Cobben, Junjie Tang
RPS 26.2	228	08:50-09:10	User Friendly Generator Maintenance Scheduling Simulation System based on Probabilistic Methodology	Yeonchan Lee, Jaeseok Choi, Myeunghoon Jung
RPS 26.3	241	09:10-09:30	Effects of Risk Aversion on Market Outcomes: A Stochastic Two-Stage Equilibrium Model	S. Jalal Kazempour, Pierre Pinson
RPS 26.4	244	09:30-09:50	Multi-objective Optimal Control Research For WTGS	Jun Liu, Guangyi Wang, Mingyue Qi

Session 27	**Uncertainties and correlations of wind power(2)**			Wednesday Oct. 19, 08:30-10:10AM
Chair	**Lalit Goel, Nanyang Technological University, Singapore**			**Friendship Palace Conference Room 1**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 27.1	54	08:30-08:50	Probability Interval Optimization for Optimal Power Flow Considering Wind Power Integration	J. J. Chen, Q. H. Wu
RPS 27.2	65	08:50-09:10	Modeling Wind Power Uncertainty in the Long-Term Operational Reserve Adequacy Assessment: a Comparative Analysis between the Naïve and the ARIMA Forecasting Models	Leonel Carvalho, João Teixeira, Manuel Matos
RPS 27.3	165	09:10-09:30	Cumulant-based Probabilistic Load Flow Analysis of Wind Power and Electric Vehicles	Pouya Amid, Curran Crawford
RPS 27.4	178	09:30-09:50	Research on the Periodicity of Wind Power Based on the Maximum Entropy Spectrum Estimation	Haixiang Xu, Linlin Wu, Hui Liu, Ruoyang Wang, Zhengpai Cui
RPS 27.5	196	09:50-10:10	Forecast Uncertainty Modeling and Data Management for a Cutting-edge Security Assessment Platform	Emanuele Ciapessoni, Diego Cirio, Andrea Pitto, Nicolas Omont

Session 28	**Uncertainties in power systems(1)**			Wednesday Oct. 19, 08:30-10:10AM
Chair	**Wijarn Wangdee, King Mongkut's University of Technology North Bangkok, Thailand**			**Friendship Palace Conference Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 28.1	68	08:30-08:50	Probabilistic Analysis for Low Voltage Ride Through Data of Doubly Fed Induction Generators in China	Can Chen, Pengfei Cao, Chen Shen, Linlin Wu, Chanan Singh
RPS 28.2	136	08:50-09:10	Optimal Configuration of User Side Integrated Energy System Based on Chance Constrained Programming	Chen Jia, Muke Bai, Chao Zhang, Jing Zhou, Gongbo Liu, Sheng Xu, Wei Tang, Cong Wu, Chenjun Sun
RPS 28.3	148	09:10-09:30	Modeling of Operational Availability of offshore Wind Turbines	Lingling Huang, Jialin Cao, Yang Fu
RPS 28.4	157	09:30-09:50	Optimal Power Flow with Worst-case Scenario Considering Uncertainties of Loads and Renewables	Chengquan Ju, Peng Wang
RPS 28.5	163	09:50-10:10	Probabilistic Analysis of the Effect of Wind Speed Variations on Power Quality of Power Systems	Mayssam Amiri, Bagen Bagen, Aniruddha M. Gole

Session 29	**Uncertainties of wind power(1)**			Wednesday Oct. 19, 08:30-10:10AM
Chair	**Aydogan Ozdemir, Istanbul Technical University, Turkey**			**Friendship Palace Conference Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 29.1	18	08:30-08:50	Optimal Scheduling of Primary Reserve in the System with High Penetration of Wind	Fei Teng, Goran Strbac
RPS 29.2	203	08:50-09:10	Wind Power Curtailment Evaluation Based on EOF and Hierarchical Clustering Method	Youjia Wang, Zongxiang Lu, Ying Qiao, Zhengpai Cui, Rongfu Sun
RPS 29.3	213	09:10-09:30	Impact of Wind and Solar Variability on the Resource Adequacy for North American Bulk Power System	Noha Abdel-Karim, Mark Lauby, David Calderon, John Moura, Thomas Coleman
RPS 29.4	240	09:30-09:50	Impact of High Wind Penetration on Variability of Unserved Energy in Power System Adequacy	Sarah Sheehy, Gruffudd Edwards, Behzad Kazemtabrizi, Chris Dent, Matthias Troffaes, Simon Tindemans
RPS 29.5	251	09:50-10:10	A Unified Analysis of the Impacts of Stochasticity and Low Inertia of Wind Generation	Nga Nguyen, Mohammed Benidris, Joydeep Mitra

Session 30	**Uncertainties of wind power(2)**			Wednesday Oct. 19, 08:30-10:10AM
Chair	**Juan Yu, Chongqing University, China**			**Friendship Palace Conference Room 4**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 30.1	32	08:30-08:50	Resource Strength and Location Impact of Wind Power on Bulk Electric System Reliability	Rajesh Karki, Sabbir Arman, Roy Billinton
RPS 30.2	128	08:50-09:10	The Reactive Power Optimization of Distribution Network based on Wind Power Output Scenario and Complete-bus Load	Qianjin Gui, Xiangqian Huang, Dabo Zhang, Hejun Yang, Yigang He, Dequan Kong
RPS 30.3	138	09:10-09:30	Probabilistic Short-circuit Analysis of Wind Power System Based on Sampling with Optimal Density Function	Shenghu Li, Zhuang Qian, Xiaoyan Zhang
RPS 30.4	200	09:30-09:50	A Heuristic for the Synthesis of Credible Operating States in the Presence of Renewable Energy Sources	Edgar Nuño, Nicolaos Cutululis
RPS 30.5	225	09:50-10:10	Capacity Credit and Reasonable ESS Evaluation of Power System including WTGs combined with BESS	Ungjin Oh, Jaeseok Choi, Hag-hyeon Kim

Regular Paper Sessions: RPS 31 - RPS 36

Wednesday October 19, 2016, 10:30-11:50AM

Session 31	**Outage data, events and analysis(1)**	Wednesday Oct. 19, 10:30-11:50AM
Chair	**Chen Shen, Tsinghua University, China**	**Building 8 Meeting Room 2**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 31.1	33	10:30-10:50	Transmission Availability Data System (TADS) Reporting and Data Analysis	Milorad Papic, Michael Clemons, Svetlana Ekisheva, Jake Langthorn, Trinh Ly, Michael Pakeltis, Richard Quest, Jeff Schaller, David Till, Kurt Weisman
RPS 31.2	72	10:50-11:10	Spatial and Temporal Clustering of Fault Events on the GB Transmission Network	Euan Morris, Keith Bell, Ian Elders
RPS 31.3	115	11:10-11:30	Wind Dependent Failure Rates for Overhead Transmission Lines Using Reanalysis Data and a Bayesian Updating Scheme	Øystein Rognes Solheim, Gerd Kjølle, Thomas Trötscher
RPS 31.4	261	11:30-11:50	Urban Distribution Grid Line Outage Identification	Yizheng Liao, Yang Weng, Chin-Woo Tan, Ram Rajagopal

Session 32	**Outage data, events and analysis(2)**	Wednesday Oct. 19, 10:30-11:50AM
Chair	**Yingzhong(Gary) Gu, General Electric, United States**	**Building 8 Meeting Room 3**

Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 32.1	17	10:30-10:50	Investigation of Equivalence between the Interstate Transition Rates and State Probabilities in the Data Analysis and Applications	Chanan Singh, Shijia Zhao
RPS 32.2	76	10:50-11:10	Synchrophasor Data Availability Analyzer	Phanuwat Phunkasem, Wijarn Wangdee, Bo Sriraphanth, Bundit Tanboonjit
RPS 32.3	108	11:10-11:30	Substation Reliability Evaluation with Dependent Outages Using Bayesian Networks	Lukasz Wojdowski, George Anders
RPS 32.4	249	11:30-11:50	Analysing Correlated Events in Power System Using Fault Statistics	Sajeesh Babu, Ebrahim Shayesteh, Patrik Hilber

Session 33	**Reliability-centered asset management**			Wednesday Oct. 19, 10:30-11:50AM
Chair	**Ning Zhang, Tsinghua University, China**			**Friendship Palace Conference Room 1**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 33.1	131	10:30-10:50	A Spare Strategy of Circuit Breakers Considering Aging Failures	Fachi Chen, Yi Dai, Zhouyang Ren, Wenyuan Li
RPS 33.2	146	10:50-11:10	The Use of Markov Chain Method to Determine Spare Transformer Number with 3-Criteria Parameters	Musa Marbun, Ngapuli Sinisuka, Nanang Hariyanto
RPS 33.3	162	11:10-11:30	The Use of Markov Chain Method to Determine Spare Transformer Location	Musa Marbun, Ngapuli Sinisuka, Nanang Hariyanto
RPS 33.4	169	11:30-11:50	Multi-criteria Optimization of Maintenance and Replacement Strategies in Transmission Systems	Alexander Rhein, Gerd Balzer, Raoul Boya, Christoph Eichler

Session 34	**Reliability-centered maintenance**			Wednesday Oct. 19, 10:30-11:50AM
Chair	**Andrea Pitto, Ricerca sul Sistema Energetico - RSE SPA, Italy**			**Friendship Palace Conference Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 34.1	27	10:30-10:50	Improving the Efficiency of Maintenance and Repair of Electrical Network Equipment	Elena Rychagova, Vladimir Levin
RPS 34.2	87	10:50-11:10	Determination of Optimal Component Maintenance Process for RCAM of Power Transmission System Using TOPSIS Method	H.Aysun Koksal, Aydogan Ozdemir
RPS 34.3	205	11:10-11:30	Reliability-Centered Asset Management Using Component Reliability Importance	Ebrahim Shayesteh, Patrik Hilber
RPS 34.4	246	11:30-11:50	Reliability Evaluation of Power Systems Incorporating Maintenance Policy with Partial Information	Youping Fan, Dai Zhang

Session 35	**Risk management and decision-making(2)**			Wednesday Oct. 19, 10:30-11:50AM
Chair	**Zhouyang Ren, Chongqing University, China**			**Friendship Palace Conference Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 35.1	86	10:30-10:50	A Stochastic Production Simulation Model for Renewable Integration and System Flexibility Studies	Shucheng Liu, Wenxiong Huang, Yi Zhang
RPS 35.2	209	10:50-11:10	Overvoltage Risk Analysis in Distribution Networks with High Penetration of PVs	Saeed Alyami, Yang Wang, Caisheng Wang
RPS 35.3	219	11:10-11:30	A Comparative View of Risk Management in Financial Sector and in Next Generation Power Grid Operation	John Jiang, Chongqing Kang
RPS 35.4	231	11:30-11:50	Zonal Operating Reserve Demand Curve Applied to Day-ahead Deterministic Unit Commitment	Meng Xu, Chris J Dent, Amy Wilson

Session 36	**State monitoring and application**			Wednesday Oct. 19, 10:30-11:30AM
Chair	**Noha Abdel-Karim, North American Electric Reliability Corporation, United States**			**Friendship Palace Conference Room 4**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 36.1	151	10:30-10:50	Condition Monitoring and Reliability Analysis of Power Systems for Underground Cavern Facilities	Zhongqiang Ding, Yuxiang Zhang, Tao Wang, Qianggang Wang, Zhen Lu, King Jet Tseng, Peng Wang
RPS 36.2	152	10:50-11:10	Condition Monitoring and Reliability Analysis of Underground Transformers	Qianggang Wang, Tao Wang, Yuxiang Zhang, Zhen Lu, Zhongqiang Ding, King Jet Tseng, Peng Wang
RPS 36.3	170	11:10-11:30	Power Line Online Fault Warning Method Based on Operational Reliability and Decision Tree	Tao Cheng, Lei Chen, Fei Xu, Yuanhang Dai

Regular Paper Sessions: RPS 37 - RPS 41

Wednesday October 19, 2016, 14:00-15:40PM

Session 37	**wind power Forecasting(1)**			Wednesday Oct. 19, 14:00-15:20PM
Chair	**Mahmud Fotuhi-Firuzabad, Sharif University of Technology, Iran**			**Building 8 Meeting Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 37.1	42	14:00-14:20	Wind Power Forecast Based on Cloud Model	Mao Yang, Qiongqiong Yang
RPS 37.2	132	14:20-14:40	The Advanced Evaluation Method of Regional Wind Power Prediction	Yu Liu, Kai Bai, Qi Yao, Yang Cui
RPS 37.3	187	14:40-15:00	Probabilistic Short-term Wind Power Forecasting Based on Deep Neural Networks	Wenzu Wu, Kunjin Chen, Ying Qiao, Zongxiang Lu
RPS 37.4	188	15:00-15:20	Wind Power Correction Method Including Multiple Factors Such as Wind-Abandon Coefficient	Xiaogang Wu, Zongxiang Lu, Ying Qiao, Rongfu Sun, Ruoyang Wang

Session 38	**wind power Forecasting(2)**			Wednesday Oct. 19, 14:00-15:20PM
Chair	**Junjie Tang, Chongqing University, China**			**Building 8 Meeting Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 38.1	30	14:00-14:20	Data Completing of Missing Wind Power Data Based on Adaptive BP Neural Network	Mao Yang, Jian Ma
RPS 38.2	37	14:20-14:40	Uncertainty Analysis of Wind Power Prediction Based on Granular Computing	Mao Yang, Chunlin Yang
RPS 38.3	57	14:40-15:00	Short-term Wind Speed Forecasting Method Based on Wavelet Packet Decomposition and Improved Elman Neural Network	Ruili Ye, Zhizhong Guo, Ruiye Liu, Jiannan Liu
RPS 38.4	69	15:00-15:20	A Review of Wind Power Forecasting & Prediction	Mao Yang, Shaoshuai Wang

Session 39		**Uncertainties in power systems(2)**		Wednesday Oct. 19, 14:00-15:20PM
Chair		**Tao Hong, University of North Carolina at Charlotte, United States**		**Friendship Palace Conference Room 1**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 39.1	197	14:00-14:20	Net Transfer Capacity Assessment Using Point Estimate Method for Probabilistic Power Flow	Matteo Saviozzi, Francesco Adinolfi, Stefano Massucco, Federico Silvestro, Emanuele Ciapessoni, Diego Cirio, Andrea Pitto
RPS 39.2	243	14:20-14:40	Optimal Feeder Reconfiguration and Distributed Generation Placement for Reliability Improvement	Yuting Tian, Mohammed Benidris, Samer Sulaeman, Salem Elsaiah, Joydeep Mitra
RPS 39.3	247	14:40-15:00	Provision of Rotating Reserves From Wind Power in a Hydro-dominated Power System	Martin N. Hjelmeland, Camilla T. Larsen, Magnus Korpås, Arild Helseth
RPS 39.4	266	15:00-15:20	An Analytical Framework for Operational Reliability Studies of Highly Wind Integrated Power Systems	Zohreh Parvini, Ali Abbaspour, Mahmud Fotuhi-Firuzabad, Moein Moeini-Aghtaie

Session 40		**Applications of probabilistic methods**		Wednesday Oct. 19, 14:00-15:20PM
Chair		**Rajesh Karki, University of Saskatchewan, Canada**		**Friendship Palace Conference Room 2**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 40.1	122	14:00-14:20	Probabilistic Estimation of the Voltage Total Harmonic Distortion in Secondary Distribution Networks	Elson Silva, Anselmo Rodrigues, Maria da Guia da Silva
RPS 40.2	129	14:20-14:40	Research on Probabilistic Reactive Power Optimization Considering the Randomness of Distribution Network	Keyan Liu, Tingting Zhao, Dongli Jia, Kaiyuan He, Fengzhan Zhao
RPS 40.3	230	14:40-15:00	House Events Matrix for Shutdown Probabilistic Safety Assessment	Marko Cepin
RPS 40.4	257	15:00-15:20	Impact Evaluation of the Network Geometric Model on Power Quality Indices using Probabilistic Techniques	Mauro Rosa, Gabriel Bolacell, Ivo Costa, Diego Issicaba, Dianne Calado

Session 41	**Reliability of DC grids**			Wednesday Oct. 19, 14:00-15:00PM
Chair	**Saeed Alyami, Wayne State University, United States**			**Friendship Palace Conference Room 3**
Session	***Paper ID***	***Time***	***Title***	**Author(s)**
RPS 41.1	160	14:00-14:20	Adequacy and Safety Comprehensive Evaluation for Ultra-high Voltage AC/DC Mixed Power Grid	Yunting Song, Wei Tang, Linna Zhang, Haitao Yang, Jingjing Wang, Ping Ji, Xiaofei Hu, Wenfei Liu, Xuxia Li, Cheng Yang, Ludeng Liu
RPS 41.2	193	14:20-14:40	VSC's Reactive Power Limited Probabilistic Power Flow for AC/DC Grids Incorporating Uncertainties	Sui Peng, Junjie Tang, Ruijin Liao, Weizhou Wang
RPS 41.3	194	14:40-15:00	Reliability Analysis Method of AC Distribution Network with Multi-terminal DC Interconnection	Lin Cheng, Xu Wang, Yao Chang, Fulong Song, Yi Gao, Ying Wang

PAPER ABSTRACTS

Paper ID	Title, Author(s), Affiliation, Abstract

1

Framework for System Analyses of Smart Grid Solutions with examples from the Gotland case

Carl Johan Wallnerström, Patrik Hilber,
Lina Bertling Tjernberg, Jan Henning Jürgensen
KTH Royal Institute of Technology, KTH Royal Institute of Technology
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This paper presents results from a study on the impact of smart grid solutions, which includes development of a generic framework for power system analyses. The study has been performed as one of several independent studies, part of a national governmental task on smart grid in Sweden. A large amount of weather data, along with electricity consumption and wind power generation data, have been analyzed. Achieved results from these initial analyses can be used as reference material and have also been used within case studies presented.
The proposed framework is flexible and numerous combinations of scenarios are possible to define. Integration of wind and solar power, analyses of transfer limits using static or dynamic rating and energy storage can be considered as well as weather effects. Results show how power systems can handle more electricity consumption and generation. The study shows that Smart Grid solutions are beneficial for resource efficient electricity grids. Moreover, different risk levels with respect to increased load can be included. Case study results show that energy storages most of the time will be unused, but that they can be used to increase the system reliability.

13

Simplified Reliability Evaluation formulae for Overhead Medium Voltage Distribution Networks

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Chongqing, China
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For the reliability evaluation of overhead medium voltage distribution networks, the required data of traditional methods are too big to be collected and inputted. Moreover, some data of a distribution power grid, especially the planning distribution networks, cannot be completely provided. As a result, it is necessary to put forward simplified reliability evaluation formulae. In this paper, the simplified evaluation formulae of system average interruption duration and frequency indexes for failure outage and scheduled interruption are deduced respectively, considering the influences of not only the main lines, distribution transformers and switches of a single type, but also big lateral lines and various types of switches, thus making the formulae more practical. Moreover, according to the interruption times based on the line length or the line segment number, two sets of evaluation formulae of scheduled interruption are deduced. The reliability evaluation of IEEE RBTS-Bus2 is performed by using the deduced formulae, and the results of better precision are obtained with little increased input data.

Paper ID	Title, Author(s), Affiliation, Abstract

15 **The probabilistic approach to determine the reliability of synchrophasor-based damping controllers**

A. I. Konara, University of Manitoba, Manitoba, Canada
U. D. Annakkage, University of Manitoba, Manitoba,Canada
Bagen Bagen, Manitoba Hydro, Manitoba,Canada

This paper presents a probabilistic approach to evaluate the reliability of a synchrophasor-based multi-input damping controller. Considering the probabilities of losing input signals to the controller, expected damping for the critical electromechanical oscillatory modes are determined. A two input power system stabilizer that uses a local and a remote signal is considered as a test system to evaluate the expected damping. Different probabilities of failures are considered for different controller inputs and the resultant expected damping values are compared. The importance of using a probabilistic index in the design stage of a controller is highlighted.

16 **Literature Review of Power System Stochastic Stability**

Hao Jiang, Hui Liu, Linlin Wu, Haixiang Xu
State Grid Jibei Electric Power Research Institute
Beijing, China

Power system stability is a traditional yet important topic in power system research. Deterministic models have been used for study of power systems stability. However, the stochastic features of power system have great impacts on the stability of power systems which cannot be ignored. In this paper, we review existing literatures using Stochastic Differential Equations (SDE) for analyzing power system stochastic transient, voltage and small-signal stability. The preliminaries of SDE are also introduced for better understanding the whole paper. The stochastic features of power systems would lead to power system instability. Therefore, it is necessary to study further on this topic.

17 **Investigation of Equivalence between the Interstate Transition Rates and State Probabilities in the Data Analysis and Applications**

Chanan Singh, Shijia Zhao
Texas A&M University
College Station, USA

Conditions for equivalence of state probabilities obtained from the data on state residence times and those from data on interstate transitions are explored in this paper. The derived conditions are useful in applications under various situations. The situations illustrated in this paper include when data is available only for state residence times but a state transition rate matrix needs to be developed for purposes of application. A situation is also illustrated when data on state residence times and interstate transitions is collected but inaccuracies may exist in the collection or processing of interstate data. Another condition explored is the effect of the probability distribution of state residence times on the reliability indices.

Paper ID	Title, Author(s), Affiliation, Abstract

18 **Optimal Scheduling of Primary Reserve in the System with High Penetration of Wind**

Fei Teng[1], Goran Strbac[2]
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London, UK
[2]Electrical Energy Systems with Imperial College London
London, UK

Due to the variability, uncertainty and limited inertia capability, high penetration of wind generation will increase the requirement on various reserve services, including both longer-term reserves and primary reserve. Although the importance of optimal scheduling of longer-term reserves has been widely studied, the scheduling of primary reserve has not yet been fully investigated. In this context, this paper proposes a novel mixed integer linear programming formulation for a stochastic unit commitment model that simultaneously optimizes both longer-term reserves and primary reserve. The optimal amount of UFLS is explicitly calculated. The value of lost load is used as the single security measure so that the model optimally balances the cost of various reserve services provision against the benefit of reduced load shedding. The proposed model is applied in a GB 2030 low carbon electricity system with different installed capacities of wind generation to demonstrate the effectiveness of the proposed approach.

19 **Evaluation of Transmission Network Reinforcements in an Automated Network Planning Process**

Helge Pluntke, Marco Weisenstein, Wolfram H. Wellssow
University of Kaiserslautern
Kaiserslautern, Germany

The identification of cost-efficient transmission network reinforcements is a tough challenge due to many uncertainties and the complexity of the optimization problem. This paper presents an Automated Network Planning Process (ANEPP) which applies a Particle Swarm Optimization (PSO). Six alternative PSO fitness functions are postulated. They differ in the number of assessed overloads and in the way reinforcements that mitigate but do not eliminate these overloads are treated. The ANEPP creates expansion plans with each fitness function. The results are evaluated in terms of total cost and computational burden to give a recommendation for an appropriate PSO fitness function.

20 **Determining A Critical Contingency Set Using Probabilistic Performance Indexes**

Jun Zhong[1], Hailei He[2], Bo Hu[1], Qinyong Zhou[2], Wenyuan Li[1]
[1]Chongqing University
Chongqing, China
[2]China Electric Power Research Institute
Beijing, China

This paper proposed a method for determining a critical contingency set for detailed power system analysis studies. The K-means clustering is applied to reduce operation scenarios in a power system. The performance indices with and without probabilities of system states are used to rank contingencies. The top contingencies ranked by the proposed performance indices are combined with additional extreme contingencies specified by experienced engineers to establish the critical contingency set. The proposed method is applied to the IEEE-RTS system

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and a real grid in Jiangxi province of China. The results demonstrate the effectiveness of the proposed method.

21 **A Performance and Maintenance Evaluation Framework for Wind Turbines**

Peyman Mazidi, Mian Du,
Lina Bertling Tjernberg
KTH Royal Institute of Technology
Stockholm, Sweden

Miguel A. Sanz Bobi
Comillas Pontifical University
Madrid, Spain

In this paper, a data driven framework for performance and maintenance evaluation (PAME) of wind turbines (WT) is proposed. To develop the framework, SCADA data of WTs are adopted and several parameters are carefully selected to create a normal behavior model. This model which is based on Neural Networks estimates operation of WT and aberrations are collected as deviations. Afterwards, in order to capture patterns of deviations, self-organizing map is applied to cluster the deviations. From investigations on deviations and clustering results, a time-discrete finite state space Markov chain is built for mid-term operation and maintenance evaluation. With the purpose of performance and maintenance assessment, two anomaly indexes are defined and mathematically formulated. Moreover, Production Loss Profit is defined for Preventive Maintenance efficiency assessment. By comparing the indexes calculated for 9 WTs, current performance and maintenance strategies can be evaluated, and results demonstrate capability and effectiveness of the proposed framework.

22 **Probabilistic Load Flow: a Business Park Analysis, Utilizing Real World Meter Data**

Alexander C. Melhorn[1], Aleksandar Dimitrovski[2], Andrew Keane[1]
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Oak Ridge, TN USA

With the introduction of higher levels of renewables and demand response programs, traditional deterministic power system tools fall short of expectation. Probabilistic load flow takes into account the uncertainty, formed by inconsistent or unknown loads and generation, in the fundamental load flow analysis. Previous works have assumed the input variables to independent. This paper applies real world meter data into the probabilistic load flow simulation, making it no longer valid to just assume independence or total correlation between the inputs without further analysis. Meter data, in 5 or 15 minute intervals, of a typical southeastern United States business park are utilized for the analysis. Since the data are incomplete, several assumptions are made for the input variables. Two different load correlation scenarios are analyzed and the probabilistic load flow results are validated by comparison of available power flow and voltage meter data. The real world data test case further confirms the validity of the proposed probabilistic load flow technique which provides an accurate and practical way for finding the solution to stochastic problems occurring in power distribution systems.

Paper ID	Title, Author(s), Affiliation, Abstract

23 **Developing a Benchmark Test System for Electric Power Grid Cyber-Physical Reliability Studies**

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[2]Texas A&M University
College Station, USA

Reliability test systems are used as a benchmark tool to test and validate probabilistic methods developed for power systems reliability evaluation. The IEEE Reliability Test System (RTS) and the Roy Billinton Test System (RBTS) are the two most widely used test systems for studying new ideas of power system reliability analysis. With the increasing penetration of Information and Communication Technologies (ICTs), modern power system performance is becoming increasingly dependent on cyber infrastructure. To facilitate the development of methods to quantitatively evaluate the impact of cyber failures on power system reliability, it is necessary to develop a reliability test system that incorporates ICT features. This paper proposes the idea of developing a cyber-physical reliability test system. A portion of the IEEE RTS is extended with ICT configurations as an example to illustrate this idea. Technical considerations and challenges in developing a large cyber-physical reliability test system are also discussed with feasible solutions suggested. The purpose of this paper is to propose initial thoughts of developing a benchmark test system for electric power grid cyber-physical reliability studies, based on which a full-fledged system can be established later with cumulative efforts and inputs from both academia and industry.

27 **Improving the efficiency of maintenance and repair of electrical network equipment**

Elena Rychagova
Novosibirsk State Technical University
Novosibirsk, Russia

Vladimir Levin
Novosibirsk State Technical University
Novosibirsk, Russia

The problem of distributive electric network operation upgrading efficiency in terms of selecting the optimum strategy of maintenance of its components is considered. Maintenance and repair of the distributive network components are controllable random processes. For its description the homogeneous semi-Markov model with discrete conditions and continuous time is developed. Based on the complex criterion "expenses - reliability" the optimization of the transmission and distribution equipment maintenance is carried out.

28 **A Smart Grid Metrics Assessment of Distribution Automation for Reliability Improvement**

Han Rui, Wolfram H. Wellssow
University of Kaiserslautern
Kaiserslautern, Germany

Deregulation and the massive growth of Distributed Generation (DG) in distribution networks are forcing the network operators to improve the operational efficiency and power quality at the distribution level. Distribution Automation (DA) enables operators to monitor and control various distribution system components and thus decrease the restoration time after a fault occurs. To implement DA properly, it is necessary to integrate communication and information

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systems and automation devices. In this paper, DA measures are modeled based on the supply restoration process. Different levels of automation are assessed by the Smart Grid Metrics (SGM) approach with respect to reliability improvement [1]. Several traditional grid concepts are modeled and compared with DA options. An analytical Probabilistic Reliability Calculation (PRC)approach is applied to calculate the reliability indices to quantify the benefits. Finally, a cost/benefit analysis is carried out in order to assess DA from both a technical and an economic point of view.

29 **Stochastic Small Disturbance Stability Analysis of Multi-machine System Based on Energy Function**

Rui WANG, Jie WANG, Xiao Mi
Shanghai Jiao Tong University
Shanghai, China

Power system is a nonlinear network with many stochastic disturbances. Recently, with large-scale renewable power integration such as wind power and solar energy, it has caused much more stochastic factors in the power system. The traditional deterministic linear analysis methods need to be improved. Therefore, it has important value to use nonlinear differential equations to analyze the stochastic small disturbance stability of multi-machine system. In view of high dimensional and nonlinear factors in the multi-generator system, the nonlinear system model with random disturbances is applied in the paper and combined with the energy function method to analyze the power system stochastic small disturbance stability. The stability problem can be simplified from the complex high-dimensional vector problem into the simple one-dimensional vector problem by using energy function. Moreover, the Monte Carlo method is used to analyze the stability probability of the multi-machine system which is subject to random disturbances. The 4 machine 11 bus system is chosen as an example and the system stability probabilities under different stochastic disturbances can be got by simulation. By analyzing the simulation results, the practicality and validity of this analysis method is verified.

30 **Data Completing of Missing Wind Power Data Based on Adaptive BP Neural Network**

YANG Mao, MA Jian
Northeast Dianli University
Jilin, China

The integrity of wind power output data is of great significance for the accurate prediction of wind power and the utilization of wind energy. In this paper, it is found that the power output affected by many factors, through the analysis of the mathematical model of wind turbine, and the solution of the specific expressions of the relationship with the traditional mathematical methods is hard to find. Based on the measured data of wind field, such as fan current, rotor speed, wind direction, and so on, a kind of model based on adaptive BP neural network is proposed to fill the missing wind power data. The simulation experiment shows that the accuracy rate and the average relative error of complete data get better results, besides the quality of completed data is improved effectively.

Paper ID	Title, Author(s), Affiliation, Abstract

32 **Resource Strength and Location Impact of Wind Power on Bulk Electric System Reliability**

S. I. Arman, R. Karki,R. Billinton
University of Saskatchewan
Saskatoon, SK, Canada

The characteristics of wind energy generation are different from those of conventional energy sources. The uncertainty and variability of wind power creates considerable challenges in planning and operating an electric power system while maintaining an acceptable level of reliability. The contributions of wind energy sources to the reliability of the overall power system depend on many factors, such as the strength of the wind resource, the point of wind integration in the power grid, the generation system configuration, and the topology of the transmission network, etc. Wind energy sources are typically installed at locations with strong wind regimes. Composite generation and transmission system reliability studies can be conducted to identify the optimal network locations to inject new generation that will provide maximum reliability benefit to the system. The wind regime at an optimal bus location may, however, be relatively low. This paper illustrates the reliability benefits of wind power from both resource strength and the location points of view, and the impact of wind power diversification on the bulk system reliability.

33 **Transmission Availability Data System (TADS) Reporting and Data Analysis**

M. Papic[1], M. Clemons[2], S. Ekisheva[3]; J. Langthorn[4], T. Ly[3], M. Pakeltis[5],
R. Quest[6], J. Schaller[7], D. Till[3], K. Weisman[8]
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Ontario, Cnanda
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This paper describes the inception and basic structure of the North American Electric Reliability Corporation (NERC) Transmission Availability Data System (TADS) and ongoing activities carried out by the NERC TADS Working Group (WG). TADS data was first collected in 2008after the NERC Board of Trustees approved the collection of TADS data. This paper presents an overview of basic concepts incorporated into the TADS collection system to uniformly and consistently quantify the reliability performance of the North American bulk transmission system. This paper discusses the categorization of transmission outage events including basic definitions of reliability indicators. Additionally, analysis results obtained from outage data

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collected in TADS during the period 2010-2014 are presented.

37 **Uncertainty analysis of wind power prediction based on Granular Computing**

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Wind energy is supplying an increasing proportion of demand in the electrical grid. An accompanied problem is that the operational reliability of the power system is affected by the inherent uncertainty and stochastic variation of wind generation which also leads to the wind power forecasts of low accuracy. Therefore, the point prediction of wind power produced by a traditional deterministic forecasting model having a low level of confidence could not reflect the uncertainty of wind generation which could not meet the requirements for the safe operation of a power system. This paper aims to use the method of the non-parametric estimation to model the probability density distribution of the errors of wind power forecasts and determine the regression function based on the estimated point or deterministic wind power forecasts. The intervals of wind power predictions reaching a certain level of confidence can be employed by system operators to estimate the operation costs and the potential risks.

38 **Improved Analytic Model to Detect Hidden Failure of Protection Relays**

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Hidden failure of protection relays is one of the important reasons of cascading failure and disconnection of power systems. It is significant to improve the reliability for protection. So far, the hidden failure remains undetected. An analytic model based on protection signals is proposed to detect hidden failures of protection relays in this paper. In this model, fault location, protection start signal, protection action signal, breaker tripping signal, protection return signal and auto-re-closing signal are all treated as logic variables. To build the analytic model, the principles of protective relay settings and the rules of circuit breaker trips are expressed with a set of logic equations. As the model dimension is large, it is difficult to find out the analytical solution. Therefore, we use discrete particle swarm optimization to solve this model. The optimal solution of the model represents the fault location and the expected states of protective relays and circuit breakers. Finally, the comparison between the real state and expected state is used to detect hidden failures. An example demonstrates that this method can be used to check the hidden failure effectively.

39 **Transmission Expansion Planning Based on Relaxed N-1 Criteria and Reliability Indices**

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This paper proposes a new methodology to solve the transmission expansion planning (TEP) problem based on relaxed N-1 criteria. An optimization technique is used to determine the best TEP plans through an adaptive multi-operator evolutionary approach. These plans are obtained by ensuring the N-1 security criterion and also relaxing it to accept pre-specified levels of equipment overload. The major focus is to measure probabilistically the relaxation of TEP plans through traditional reliability indices, and, consequently, the effectiveness of deterministic N-1 based approaches. Discussions are carried out using the results from two test systems: Modified IEEE-RTS and a configuration of the South Brazilian network.

40 **Spinning Reserve Assessment via Quasi-Sequential Monte Carlo Simulation with Renewable Sources**

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This paper presents a new methodology for assessing spinning reserve in generating systems with high penetration of renewable energy. A state-space model is proposed to represent the generation capacity failures and the intermittency of renewable sources based on historical scenarios. The uncertainty in the system supply is captured through risk indices that represent the probability of not meeting the short-term estimated demand. A security strategy associated with the probability distribution of reserve levels is also proposed to avoid the oversizing of reserve capacity levels to handle unlikely extreme operating points. Risk indices are estimated via quasi-sequential MCS-CE (Monte Carlo Simulation via Cross-Entropy) method, where the corresponding parameters are optimally distorted based on CE concepts. The proposed method is applied to a modified version of the IEEE RTS-79 system to cope with renewable sources.

41 **Ultra-Short-Term Prediction Intervals of Photovoltaic AC Active Power**

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The paper describes a heuristic method for the ultra-short-term computation of prediction intervals (PIs) for photovoltaic (PV) power generation. The method allows for directly forecasting the AC active power output of a PV system by simply extracting information from past time series. Two main approaches are investigated. The former relies on experimentally observed correlations between the time derivative of the PV AC active power output and the errors caused by a generic point forecast technique. The latter approach represents an improvement of the first one, where the mentioned correlations are clustered as a function of the value of the AC active power.

The work is framed in the context of microgrids and inertia-less power systems control, where

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accounting for the fastest dynamics of the solar irradiance can become extremely valuable. We validate the proposed model using one month of AC active power measurements and for sub-second time horizons: 100, 250and 500 ms.

42 **Wind power forecast based on cloud model**

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This paper presents a wind power forecast model based on cloud model, aiming at the randomness of the output power of wind turbine system. This model can solve the uncertainty of the output power of the wind power generator effectively through forming a transition model between its qualitative concepts and its ration expressions showed by numerical characteristics used specific algorithm. To make the predictions more accurate, firstly, the data is divided into an upper data and a waist data. Then these two kinds of data are analyzed separately. Secondly, the parameters of the upper data and the waist data are gotten by using known and unknown membership backward cloud generator. Finally, forward cloud generator and X conditions cloud generator are compiled separately and the Matlab program of the power cloud droplets are generated. The predictive power values can be generated after importing wind speed data. The prediction results show that the cloud model in this paper is adapted for total power prediction and the prediction results is better than other models and the accuracy of the upper data is better than the waist data by using this model.

44 **The analysis of independence of wind speed based on the probability of run-length**

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The analysis of the wind speed is of great significance to the wind power system's stable operation. There are many methods of analysis at present, they describe the time series in the frequency domain only. But it is not enough. It is necessary to make a comprehensive description not only from the frequency domain but also the time domain. In this paper, we study the independence of time series in run-length text on the basis of roulette model. The theory of run-length test and the inspection formulas are deduced in this article. Then verify the reliability of the formulas. At last, using the model ARIMA (Auto-regressive Integrated Moving Average Model) to predict the wind speed in next two hours in order to verify that the data with independence can make the wind speed's prediction results more accurate. If the data contains a lot of long run-lengths, it inevitably brings the problem that sample representative is not sufficient. Thus it reflects the necessary of the run-length text.

45 **Solutions to Probabilistic Analysis of Voltage Stability in Power Systems with Wind Farms Using Advanced Unscented Transformation**

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Paper ID	Title, Author(s), Affiliation, Abstract

This paper presents a method based on unscented transformation (UT) technique to solve probabilistic analysis of voltage stability in power system including large-scale wind farms, and the randomness of the wind farms' output power and the load increase direction are considered. UT technique is applied to transform the probabilistic analysis problem into some deterministic voltage analysis problems, and these deterministic problems are solved with interior point method. In order to improve the accuracy, a modified UT with proportion and higher order information is proposed. The numerical results of the modified IEEE 118 and 300-bus systems prove that, the proposed method is easy to be implemented and convenient to deal with the dependencies among the input random variables. Compared with Monte Carlo (MC) method, the calculation error of the proposed method does not exceed 1.5%, and efficiency can be improved several dozen times.

47 **Population Dynamics for Renewables in Electricity Markets: A Minority Game View**

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The dominance of fluctuating and intermittent stochastic renewable energy sources (RES) has introduced uncertainty in power systems which in turn, has challenged how electricity market operate. In this context, there has been significant research in developing strategies for RES producers, which however typically focuses on the decision process of a single producer, assuming unrealistic access to aspects of information about the power system. This paper analyzes the behavior of an entire population of stochastic producers in an electricity market using as basis a minority game: *the El Farol Bar problem*. We illustrate how uncomplicated strategies based on a adaptive learning rules lead to the coordination among RES producers and a Pareto efficient outcome.

48 **Hybrid Entropy Evaluation of Equipment Severity to Voltage Sags**

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The equipment severity to voltage sag is with complicated uncertain properties, including random, fuzzy and their cross uncertainty. In order to evaluate equipment severity to voltage sag occurring in power supply site, more reasonable measure and evaluation model are proposed based on the concept of classical measure and its existence conditions. Hybrid entropy formed by random entropy, fuzzy entropy and cross entropy is introduced to measure the complex uncertainties of equipment severity. Based on the maximum hybrid entropy principle, the quantitative evaluation model and approaches are proposed. The possible distribution and equipment severity described as failure rate are calculated using approximate programming method. After the random, fuzzy and cross uncertainty are determined, according to practical test data, the equipment failure rate is determined. As a case study, the

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failure rate of personal computer (PC) is evaluated and compared with probability and fuzzy methods. It has been shown that the proposed hybrid entropy method is realistic and feasible, which can avoid the over- and under-evaluation among existing methods.

49 **Comparing a Transmission Planning Study of Cascading with Historical Line Outage Data**

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The paper presents an initial comparison of a transmission planning study of cascading outages with a statistical analysis of historical outages. The planning study identifies the most vulnerable places in the Idaho system and outages that lead to cascading and interruption of load. This analysis is based on a number of case scenarios (short-term and long-term) that cover different seasonal and operating conditions. The historical analysis processes Idaho outage data and estimates statistics, using the number of transmission line outages as a measure of the extent of cascading. An initial number of lines outaged can lead to a cascading propagation of further outages. How much line outages propagate is estimated from Idaho Power outage data. Also, the paper discusses some similarities in the results and highlights the different assumptions of the two approaches to cascading failure analysis.

50 **Estimation of the Probability Density Function of Renewable Power Production using a Hybrid Method of Minimum Frequency and Maximum Entropy**

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Accurately estimating the probability distribution of renewable power production is a fundamental and challenging task in the probabilistic analysis of power systems with a high penetration of renewable energy. In this study, a novel hybrid method of minimum frequency and maximum entropy (MFME) is proposed for accurately and rapidly estimating the probability density function (PDF) of renewable power production. Based on the maximum entropy (ME) principle, a probability distribution optimization model is built to obtain a PDF estimator with the maximum distribution entropy. For convenience in solving the model, the probability density estimates of actual samples calculated by the minimum frequency (MF) method are introduced as a supplement to the moment constraints of the ME optimization model. The results indicate that the MFME has a higher accuracy compared with the conventional parameter distribution estimation(CPDE) and Gaussian kernel density estimation (GKDE), and its advantages of no boundary effects and a fast sampling speed for a large original sample size are more suitable for the PDF estimation of renewable power production.

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51 **Unit Commitment Risk Evaluation of Power Systems with PV and Energy Storage**

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As Photovoltaic (PV) penetration level rapidly increases in the modern power systems, the adoption of energy storage systems (ESS) is a preferred option to control the rapid and unpredictable PV power fluctuations. It is desired to develop new reliability evaluation methods that can model and evaluate the reliability impact of these new entries. This paper has proposed an area risk based method that can take into account the PV intermittence and ESS operations when evaluating the unit commitment risk (UCR). The rapid changes of PV power is accounted for every 5-minute interval during the lead time. A control algorithm for the ESS is also developed and integrated into the evaluation of UCR. The method is applied to quantify the effects of different ESS capacities on the system's load carrying capability. System planners can utilize this method to determine the proper ESS installation for a system with given PV penetration level. This method is also useful for system operators to decide on the required committed units as well as the charging and discharging power of ESS given PV fluctuation.

52 **Wind-solar Micro Grid Reliability Evaluation Based on Sequential Monte Carlo**

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As fossil fuels become less and less, renewable power generations such as wind and solar energy have been regarded as a current trend. However, their intermittent nature and instable output will greatly influence the stability of power system. In order to verify wind-solar hybrid generation system can greatly improve the stability of the micro grid. The study presents and analyzes the output models of wind and solar energy, then verifies by Monte Carlo sampling to get the distribution of wind energy and solar energy are consistent with Weibull and Beta distribution. Finally, micro grid power generation system with wind-solar energy is analyzed to assess the reliability indices including loss of energy expectation (LOEE) and loss of load expectation (LOLE) by sequential Monte Carlo method, the simulation results show that the parallel power generation with solar and wind energy enables to effectively improve the stability of the micro grid system.

53 **Stochastic Day-Ahead Generation Scheduling With Pumped-Storage Stations and Wind Power Integrated**

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With more and more uncertain wind power generation integrated in power systems, it is significant to enhance the resilience of generation scheduling to avoid imbalance charges. This paper proposes a stochastic day-ahead generation scheduling(SDAGS) with pumped-storage (PS) stations and wind power(WP) integrated in power systems to tackle the variability of wind power for the purpose of reliability and economy of system operation. Considering the uncertainties of load and wind power generation, Latin hypercube sampling with Cholesky decomposition (LHS-CD) is utilized to generate several scenarios. Multi-objective group search optimizer with adaptive covariance and Lévy flights (MGSO-ACL) is applied to optimize the SDAGS over 24-hour period, aiming at reaching a compromise between the minimization of expectation and variance of total cost of the SDAGS. Furthermore, a decision making method based on evidential reasoning (ER) approach is utilized to determine a final optimal solution considering expected carbon dioxide emission and expected polluted gas emission. Simulation studies are conducted on two different power systems with PS stations and WP integrated to verify the efficiency of the SDAGS.

54 **Probability Interval Optimization for Optimal Power Flow Considering Wind Power Integrated**

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This paper presents a probabilistic interval optimization (PIO) model for evaluating the problem of optimal power flow considering wind power integrated (OPFWP). In PIO model, the wind power is deemed as a probability interval variable to assess its profit and risk simultaneously. To be precise, the profit is manifested by the net decrease of generation cost between the same power system with and without wind power integrated, and the risk is assessed by the distribution probability of wind power. Then the optimization objective of OPFWP is formulated as the conditional expectation of profit. Numerical tests obtained based on a modified IEEE 30-bus system demonstrate the effectiveness of the PIO model for evaluating OPFWP.

55 **Two-stage Stochastic Programming Based Model Predictive Control Strategy for Microgrid Energy Management under Uncertainties**

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Microgrids (MGs) are presented as a cornerstone of smart grid, which can integrate intermittent renewable energy sources (RES), storage system, and local loads environmentally and reliably. Due to the randomness in RES and load, a great challenge lies in the optimal operation of MGs. Two-stage stochastic programming (SP) can involve the forecast uncertainties of load demand, photovoltaic (PV) and wind production in the optimization

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model. Thus, through two-stage SP, a more robust scheduling plan is derived, which minimizes the risk from the impact of uncertainties. The model predictive control (MPC) can effectively avoid short sighting and further compensate the uncertainty within the MG through a feedback mechanism. In this paper, a two-stage SP based MPC stratey is proposed for microgrid energy management under uncertainties, which combines the advantages of both two-stage SP and MPC. The results of numerical experiments explicitly demonstrate the benefits of the proposed strategy.

57 **Short-term wind speed forecasting method based on wavelet packet decomposition and improved Elman neural network**

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Accurate prediction of wind speed is of great significance to the operation and maintenance of wind farms, the optimal scheduling of turbines and the safe and stable operation of power grids. This paper puts forward a new method for short-term wind speed forecasting based on the wavelet packet decomposition(WPD) theory and an improved Elman neural network(ENN), and the concrete application steps of the method is given. WPD theory is firstly adopted to decompose wind speed data into several wavelet spaces, and according to the correlation, the optimal decomposition tree will be persisted and random data will be rejected. Then a new particle swarm optimization (PSO) training algorithm with disturbance is proposed to improve the training speed of neural networks and deal with the drawback of PSO's easily falling into local optimal solution. Finally, ENNs with different structures are established and used to find the laws of wind speed in different frequency bands, prediction results are hence received. The correctness and effectiveness of the proposed method is verified by wind speed data of a wind farm in south China.

59 **A Review and Discussion of Failure Rate Heterogeneity in Power System Reliability Assessment**

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The failure rate is a reliability measure which is used for planning and operation of the power system. Thus far, average or experience based failure rates were applied to power system equipment due to their straightforward implementation. However, this approach limits the accuracy of the gained results and neglects the important differentiation between population and individual failure rates. Hence, this paper discusses and demonstrates the necessity to distinguish between population and individual failure rates and reviews the existing literature of failure rate estimation within the power system domain. The literature is categorized into statistical data driven approaches and failure rate modelling with focus on different criteria which can be used to describe the heterogeneity within populations. The review reveals that the environmental impact was modelled predominantly.

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60 **Wind Power Accommodation Considering the Prediction Error of Wind Power**

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Wind power forecast error has been considered to be the factor that increases the difficulty of power system dispatch, decreases the economy of system operation, and affects the wind power accommodation. A multiple time scales dispatch model of wind power integrated system is built considering the wind power forecast error and demand response. The price-based demand response (PDR) is used in the initial dispatch because of the large day-ahead forecast error. In the day, the price-based demand response is dispatched again to take advantage of its low cost. According to the strong timeliness of the incentive-based demand response (IDR), it is used in real-time dispatch to decrease the influence of wind power forecast error on the system dispatch and wind power accommodation. Study case shows that the multiple time scales optimal dispatch can increase wind power accommodations, save system operating costs, ensure the autonomy of consumers and reduce the impact of demand response.

61 **Research on Reliability Evaluation Method of Catenary of High Speed Railway Considering Weather Condition**

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Weather condition has a great influence on the reliability assessment of the high-speed railway catenary system. This paper proposes a reliability assessment method for high-speed railway catenary system considering weather conditions. The weather condition is classified according to IEEE standard, and the failure rate model of catenary component is built under three weather conditions. Then the failure rate and repair rate under different weather conditions are considered as random fuzzy variables. Credibility theory is applied to evaluate the influence of uncertainties on the reliability assessment of catenary system. Finally, fault tree analysis method is introduced to calculate the reliability indices of the catenary system. Case study shows the proposed method achieves reliability assessment for catenary of high-speed railway system considering the influence of weather conditions, and the reliability indices under different weather conditions are obtained.

62 **Comparing Two Model Selection Frameworks For Probabilistic Load Forecasting**

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Model selection is an important step for both point and probabilistic load forecasting. In the point load forecasting literature and practices, point error measures, such as mean absolute percentage error (MAPE), are often used for model selection. On the other hand, many probabilistic load forecasting methodologies rely on the model selection mechanism developed for point load forecasting. In other words, the models for probabilistic load forecasting are selected to minimize point error measures rather than probabilistic ones, such as quantile

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score. Intuitively, selecting models for probabilistic forecasting based on a point error measure is less computationally intensive and less accurate than its counterpart. The practical question is whether we can gain significant accuracy by taking the more computationally intensive route. This paper presents a comparative study on model selection for probabilistic load forecasting, using point and probabilistic error measures respectively. The data for the case study is from the load forecasting track of the Global Energy Forecasting Competition 2014. We find that the two model selection mechanisms indeed return different underlying models. While on average, the models from quantile score based model selection method can lead to more accurate probabilistic forecasts, the improvement over the MAPE based model selection method is marginal.

64 **Approximate Active Power Distributions for Standard Household Loads**

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The large feed-ins of photovoltaic (PV) systems in low voltage (LV) grids result in increasing voltage magnitudes and line loadings. While the rise of voltage magnitudes can be limited e.g. by distribution transformers (DTs) with on-load tap changers, high line loadings cannot even be detected by network operators due to a lack of network observability. LV state estimation (SE) systems can provide a way to determine the required network states and line loadings. Measured operational network variables, e.g. voltage magnitudes and power values of PV systems, can be used as input data for the SE. Nevertheless, power measurements of households are not available and thus the household loads have to be approximately determined. This paper presents approximate active power distributions (AAPDs) for standard household loads, derived on the basis of field-trial data. They are an innovative way for the necessary generation of active power pseudo-values (APPVs) for LV SE with statistical errors following a Gaussian distribution. Despite the simplicity of the AAPDs the errors made within the current calculation is acceptable.

65 **Modeling Wind Power Uncertainty in the Long-Term Operational Reserve Adequacy Assessment: a Comparative Analysis between the Naïve and the ARIMA Forecasting Models**

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The growing integration of renewable energy in power systems demands for adequate planning of generation systems not only to meet long-term capacity requirements but also to cope with sudden capacity shortages that can occur during system operation. As a matter of fact, system operators must schedule an adequate amount of operational reserve to avoid capacity deficits which can be caused by, for instance, overestimating the wind power that will be available. The framework proposed for the long-term assessment of operational reserve relies on the Naïve forecasting method to produce wind power forecasts for the next hour. This forecasting model

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is simple and widely used to obtain short-term forecasts. However, it has been shown that regression models, such as the Autoregressive Integrated Moving Average (ARIMA) model, can outperform the Naïve model even for forecasting horizons of up to 1 hour. This paper investigates the differences in the risk indices obtained for the long-term operational reserve when using the Naïve and the ARIMA forecasting models. The objective is to assess the impact of the forecasting error in the long-term operational reserve risk indices. Experiments using the Sequential Monte Carlo Simulation (SMCS) method were carried out on a modified version of the IEEE RTS 79 test system that includes wind and hydro power variability. A sensitivity analysis was also performed taking into account several wind power integration scenarios and two different merit orders for scheduling generating units.

68 **Probabilistic Analysis for Low Voltage Ride Through Test Data of Doubly Fed Induction Generators in China**

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An important aspect of research on integrating wind farms is the analysis of short circuit current contribution to the power grid. In this paper, the fault related features of doubly fed induction generators(DFIGs) are modeled using low voltage ride through(LVRT) test data sets. The dynamic behavior of DFIGs after fault occurrence is represented by a typical curve that is obtained using a curve clustering technique-the backward scenario reduction method. Then, two fault features(the maximum value of the short circuit current termed as peak current and the time to reach it), which are important for protection relay settings, are collected and analyzed using the probability density functions(PDFs). Two cases are considered in the analysis and some discussions are presented in the end.

69 **A Review of Wind Power Forecasting & Prediction**

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Due to the stochastic and intermittent nature of wind power, the accuracy of wind power prediction(WPP) is of great significance to the grid with increasing wind farm penetration. Currently the methods of WPP is various and uneven. Hence forecasting methods are detailedly classified and summarized in this paper, and the basic ideas, advantages and disadvantages of these methods are discussed in detail. The paper presents the analysis of state-of-the-art worldwide research, and the outlook of the main research directions of WPP.

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70 **Analysis of Cascading Failure Considering Load-shedding strategy and Failure Correlation**

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It is well known that cascading failure is one of the key factors which lead to blackout events around the world. How to simulate cascading failure reasonably is one of the important issues to be solved by electrical engineers. An ad-hoc cascading failure model based on probabilistic line outage and failure correlation is proposed in this paper. The proposed model involves AC power flow computation and all possible cases of cascading failure. In this model, some measures including the load shedding strategy and subsequent failure search strategy as well as probabilistic selection of line outage are taken into account during analysis. In addition, some risk indices are introduced to evaluate the vulnerability of power system caused by cascading failure. Finally, simulations performed on IEEE-39 bus test system demonstrate the validity and effectiveness of the proposed model and method as well as drawing some meaningful conclusions.

72 **Spatial and Temporal Clustering of Fault Events on the GB Transmission Network**

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The UK is subject to changing weather patterns due to the global process of climate change. The full extent of these changes is not currently known; however, it is possible that the UK will be subject to more extreme or more frequent severe weather events (or both). As 50% of the faults on the transmission network in Britain are weather related it is likely that any change in weather patterns for the worse would increase the number of faults the network experiences. This paper describes a review of fault records in one region of the UK in order to understand the potential impact on system operation of clusters of weather related network faults. Based on the patterns of identified clusters, it suggests some potential impacts of climate change.

74 **Transmission Network Expansion Planning With Stochastic Multivariate Load and Wind Modeling**

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The increasing penetration of intermittent energy sources along with the introduction of shiftable load elements renders transmission network expansion planning (TNEP) a challenging task. In particular, the ever-expanding spectrum of possible operating points necessitates the consideration of a very large number of scenarios within a cost-benefit framework, leading to computational issues. On the other hand, failure to adequately capture the behavior of stochastic parameters can lead to inefficient expansion plans. This paper proposes a novel TNEP framework that accommodates multiple sources of operational stochasticity. Inter-spatial dependencies between loads in various locations and intermittent generation units' output are captured by using a multivariate Gaussian copula. This statistical model forms

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the basis of a Monte Carlo analysis framework for exploring the uncertainty state-space. Benders decomposition is applied to efficiently split the investment and operation problems. The advantages of the proposed model are demonstrated through a case study on the IEEE 118-bus system. By evaluating the confidence interval of the optimality gap, the advantages of the proposed approach over conventional techniques are clearly demonstrated.

75 **On Improving Data and Models on Corrective Control Failures for Use in Probabilistic Reliability Management**

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One of the most pressing concerns in the investigation of new probabilistic reliability criteria pertains to the data required as input to the evolving probabilistic models. This paper discusses an area of failure data collection that has been overlooked in power system reliability studies: corrective control actions. Background information is provided on the need for evolution of data collection systems in this context. Further, steps that can be taken to build a database of parameters necessary for modelling corrective actions are provided, to be useful in assessing system behaviour from a probabilistic reliability management perspective. Modelling of corrective control actions using event trees is illustrated. Throughout, the various challenges foreseen in the building of corresponding databases and models are outlined.

76 **Synchrophasor Data Availability Analyzer**

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Wide-area monitoring system (WAMS) is emerging technologies that utilize phasor measurement units (PMUs) combined with highly accurate time synchronization to deliver the time-synchronized phasor data known as "synchrophasor". To enable more extensive applications from WAMS, an excellent synchrophasor data availability level is a must-have. In this paper, a developed software application tool for analyzing data availability and classifying causes of unavailable data is presented. The developed software tool demonstration has been done by using the actual synchrophasor data retrieved from WAMS currently installed for Thailand power grid. The synchrophasor data analysis results based on one-month and daily availability statistics are shown using visualization charts. The results indicate that the current data availability from WAMS, on average, may not yet reach the excellent level that is adequately suitable for real-time control and protection applications. The data analysis results obtained from the developed software tool can provide insightful information to guide what the data problems might be, so that appropriate corrective actions can be implemented to improve the data availability.

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77 **Risk Pruning under Islanding Conditions Using Wind-Hydro Generation Coordination**

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This paper investigates the benefit of coordinating wind and hydro power generation to reduce system risk of a single radial supply system due to islanding conditions. In the study, hydro generating plant is considered as an equivalent energy storage capability charged using the wind power by reducing the hydro generation output to conserve the water stored in the reservoir during high wind periods, and ramp up its power output when wind power goes down. The results indicate that wind-hydro coordination can help reduce the system risk of a single radial supply system subjected to islanding conditions. The degree of the system risk reduction is, however, dependent on level of wind-hydro coordination together with constraints given by wind and hydro characteristics as well as storage (reservoir) capability.

78 **Impact of Increased Uncertainty in Power Systems on Performance of Short Term Reliability Management**

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Power system states are not accurately known ahead of real time and are subject to natural variability, which leads to uncertainty in the system. Sources of uncertainty are amongst others load, renewable energy sources and contingencies. An aggregate measure for system's uncertainty is determined in order to have a single quantified value of the uncertainty level in the system. This allows to compare performance of power system reliability management according to various reliability criteria at different uncertainty levels in a transparent manner. A case study for a 5 node test system illustrates the use of the aggregate uncertainty measure and the impact of different uncertainty levels on short term reliability management of transmission system operators according to three reliability criteria. Results of the case study illustrate that probabilistic reliability management can lead to significant improvements in performance in terms of total system cost and curtailment of non-flexible load compared to reliability management based on deterministic N-0 and N-1 criteria, especially at high uncertainty levels in heavily loaded system conditions.

79 **Near real-life pilot testing of real-time probabilistic reliability assessments**

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This paper introduces a probabilistic reliability management approach and describes a pilot test planned by the Icelandic transmission system operator, Landsnet, in early 2017, as part of the EU GARPUR project. The pilot test will assess the viability of the approach and criteria proposed

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by GARPUR, in the context of real-time system operation. The mathematical formulation of reliability assessment being studied in the pilot test and the required algorithms are outlined. Data and tools needed for the pilot test are detailed, identifying the required assumptions and simplifications where existing data and tools are lacking. Finally, the preliminary methodology of the pilot test is described, followed by a discussion of the expected value of the pilot test. It is anticipated that the pilot test will provide insights into data and modelling needs for the implementation of probabilistic risk management approaches and criteria in transmission system operation.

80 **Valuation of stored energy in dynamic optimal power flow of distribution systems with energy storage**

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Dynamic optimal power flow (DOPF) models are needed to optimize the operation of a power system with energy storage systems (ESSs) over an extended planning horizon. The optimal storage level at the end of each planning horizon depends on the possible realization of uncertainties in future planning horizons. However, most DOPF models simply require that the storage levels at the end and at the beginning of the planning horizon should be equal. In this paper we consider an AC DOPF model for a distribution system with ESS that explicitly takes into account the expected future value of stored energy. We illustrate the evaluation of the future value function for a system with a wind power plant and demonstrate the use of this value function in the operation of the ESS. The results show that such an operational strategy can be effective compared to not considering the value of stored energy.

82 **Benefits of coordinated control reserve activation and grid management – a probabilistic load flow analysis**

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Joint control reserve procurement and activation by several Transmission System Operators can have significant technical and economic benefits. In congested transmission networks, however, the activation of control reserve can be constrained by impending overloads. In this paper the benefits of an optimization to coordinate control reserve activation and grid management considering uncertainties caused by forecast errors is outlined. The effect of these uncertainties are measured by using probabilistic load flow methods based on convolution technique. A joint optimization is presented to minimize the costs of supplying control reserve and conducting redispatch, taking into account HVDC lines, variable costs of power plants and the impact of control reserve activation on lines instead of optimizing it separately as it is the current proceeding by European Transmission System Operators. In addition, a method to determine the solution space for permissible control reserve distributions is presented. In a case study of the German transmission grid for the year 2024 the costs of the

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joint optimization are contrasted to the costs using the normal merit order and additional redispatch as it is the current market scheme. With the simulation for one year, the solution spaces are calculated to show, which power plants can supply control reserve in every hour without causing redispatch measures and whether the existing power plants in 2024 are sufficient to provide control reserve activation without impending overloads.

83 **A Study on Several Hours Ahead Forecasting of Spatial Average Irradiance using NWP model and Satellite Infrared Image**

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For a stable operation of electric power system with high penetration photovoltaic power generation system (PVS), an accurate and reliable forecasting method of PVS power output should be employed. Based on the combined use of a numerical weather prediction (NWP) model and satellite images, this paper develops a several hours-ahead forecasting method of spatial average irradiance, which is a primary measure of aggregated PVS power output. Focusing on the irradiance in the morning, the proposed method utilizes satellite infrared images. First, based on the investigation of relation between brightness temperature derived from infrared image and irradiance, this paper formulates an irradiance forecasting model. Then, this paper develops a clouds motion forecasting method using forecasted wind velocity of NWP model. Finally, this paper demonstrates the improvement of forecast accuracy of spatial average irradiance compared to that of a day-ahead forecasting.

84 **Modeling Impacts of PM 2.5 Concentration on PV Power Outputs**

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PM2.5 concentration can have significant impacts on solar irradiation and thus on photovoltaic (PV) power output. This paper presents a method to model impacts of PM2.5 concentration on PV power. A non-parametric kernel density estimation is used to fit the probability distribution of PM2.5 concentration. An incremental relation between the increase of PM2.5 concentration and the decrease of solar irradiation is established for each PM2.5 level based on the PM2.5 air quality index. The simulation results using the PM2.5 and solar irradiation data in Beijing verified the effectiveness of the proposed method.

85 **A Hybrid Probabilistic Assessment Using Different Renewable Penetration Scenarios in the North American Bulk Power System**

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Paper ID	Title, Author(s), Affiliation, Abstract

This paper provides an analysis on the challenges to reliability introduced by increased penetration of Variable Energy Resources (VER) on the North American Bulk Power System (BPS).This paper highlights the importance of addressing VER availability, their inconsistent impacts to total system load, and the associated risks for system planning and operations. Further presented are risk-based approaches focusing on modeling VER with net demand uncertainties at peak intervals. The included work is part of a larger effort by the North American Electric Reliability Corporation (NERC) to demonstrate the benefits of applying probabilistic approaches for a better understanding of emerging BPS trends and to promote reliable operation and planning efforts. Hourly demand, VER (i.e., wind and solar)profiles along with their associated statistical characterization are presented for a California Independent System Operator (CAISO)case study. Peak analysis is applied to construct peak shapes using high VER penetration scenarios with differently assigned peak intervals (or signal partitions)to investigate the volatility impacts of increased wind and solar power to support further operational risk and resource adequacy assessments. The paper then proposes a hybrid model by combining these constructed peak shape sat different intervals with a risk-based, probabilistic approach using a Monte-Carlo simulation method to assign VER and net load probability distributions. Findings suggest that the amount of MW operating reserves needed at shorter peak intervals are slightly higher than longer termed intervals due to the stochastic nature of wind and solar at small timescales. In addition, this hybrid model can be used to further support operational risk and resource adequacy assessments in addressing reliability and emerging issues in a probabilistic purview. The paper concludes that balancing high VER penetration with reliability will require changes in system operation and planning measures.

86 **A Stochastic Production Simulation Model for Renewable Integration and System Flexibility Studies**

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Yi Zhang, California ISO, Folsom, CA, USA

A stochastic production simulation model was developed to evaluate the California Independent System Operator (CAISO) system capacity and flexibility sufficiency in order to integrate high volume of renewable generation to meet the California state renewables portfolio standard (RPS) goals. The model, which simulates the operation of the CAISO system, uses four stochastic variables, generation resource forced outages, load, solar and wind generation, to capture a wide range of possible system conditions. A novel pattern preserving methodology was developed to create samples of stochastic load, solar and wind generation variables. The model was used to study the system capacity and flexibility needs to integrate 33% renewable generation in California. The results of this study were filed to the California Public Utilities Commission(CPUC) in the Long Term Procurement Plan (LTPP) proceeding.

87 **Determination of Optimal Component Maintenance Process for RCAM of Power Transmission System Using TOPSIS Method**

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Paper ID	Title, Author(s), Affiliation, Abstract

Restructured electric power industry has brought to necessity of minimizing the investment costs and optimizing the maintenance costs, while improving or at least keeping the existing reliability levels. Reliability centered asset management (RCAM) aims to maximize the return on investment by optimizing the maintenance tasks. RCAM studies involve the quantification of component and sub-component criticality that will in turn dominate the component maintenance tasks. This study presents improved component criticality analysis to determine optimal component maintenance procedure for RCAM of power transmission system using Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) Method. The method is applied to Turkish National Power System RCAM studies.

88 **Reliability Evaluation of Medium Voltage Distribution Network with Private Electric Vehicle**

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Ya Chen, Bo Hu, Bo Li
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Chongqing, China

With the energy crisis and environment problem increasing prominently, as a new means of transportation, electric vehicles (EV, Electric Vehicle) will be accessed to distribution networks more and more, leading to a huge challenge on power system reliability. This paper mainly studies the reliability evaluation of medium voltage distribution network with private EV accessed. First based on the residents commuting patterns, the impact of private EV charging and discharging characteristics on the load profile is analyzed quantitatively. Based on load zoning, the optimal driving route model with the objective function of the shortest path and shortest time is proposed, which is then solved by the dynamic programming algorithm. Finally, by considering EV charging and discharging characteristics, spatial distribution characteristics, EV charging and discharging model is proposed. Then by studying the impact of distribution system failures during EV charging and discharging process, novel reliability indices are defined. Based on the considerations above, Monte Carlo simulation method based on Latin Hypercube Sampling is applied for reliability evaluation of medium voltage distribution system considering private EV accessed. A modified IEEE-RBTS Bus2 system is used as an example to analyze the impact of EV accessed ratio and EV charging mode on distribution system reliability, verifying the feasibility and effectiveness of the model and method proposed.

108 **Substation Reliability Evaluation with Dependent Outages Using Bayesian Networks**

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This paper presents an application of the Bayesian networks (BN) to substation reliability analysis. First part of the paper describes BN used to construct simple nodes, second shows the methodology used in constructing models of complex systems. A new model to represent dependent outages is introduced in the paper with a discussion how to avoid cycles when creating network models. A combination of path analysis with the Bayesian networks to

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enhance the construction of the latter is also presented.

112 **Reliability Evaluation of Electrical Collector System of Wind farm Based on Sequential Monte Carlo**

Lili Wen[1], Manli Wang[2], Ping Zhou[1], Qian Zhou[3], Bo Hu[2], Yinghao Ma[2], Yun Xia[2], Ruosong Xiao[2], Bo Li[2]

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In order to study the influence of electrical collector system of wind farm from the perspective of four typical topological structures of electrical collector system of wind farm, sequential Monte Carlo model is established for reliability evaluation of electrical collector system of wind farm with consideration of multiple faults of wind turbine generator (WTG) and collection circuit in wind farms. The influence of cable fault on outage of WTG as well as separating and switching operations of the switch is studied. A comparison of four typical topological structures in probability distribution of number of WTGs under effective operation, total outage probability of WTGs, annual energy output of wind farm and other reliability indexes is conducted through actual calculating-examples analysis. Sensitivity analysis of collection circuit fault rate is then implemented. Calculating-example results verifies the correctness and applicability of the model proposed in this paper.

115 **Wind dependent failure rates for overhead transmission lines using reanalysis data and a Bayesian updating scheme**

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Gerd Kjølle
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The main task of this paper is to calculate wind dependent failure rates for overhead transmission lines using re-analysis data and a Bayesian updating scheme. The availability of finely meshed hourly reanalysis time series for wind speed allows us to construct individual fragility curves for each transmission line by considering the failure probability of each of its segments as a function of weather exposure where both segment length and the intensity of wind has been included. Using historical failure data together with a Bayesian updating scheme we are able to construct historical hourly time series for the probability of transmission line failure. These time series form the basis of a Monte Carlo simulation that enables us to capture the significant increase in probability of the occurrence of two or more simultaneous failures associated with severe storms.

120 **Reliability evaluation of the grid-connected micro-grid considering demand response**

Ping Zhou[1], Ziyuan Chen[2],Hongqin Yang[1], Lili Wen[1], Yin Liu[1], Bo Hu[2], Yinghao Ma[2], Yun Xia[2], Ruosong Xiao[2], Bo Li[2]

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The switching in of renewable resources to micro-grids and the implementation of demand response strategy has made reliability evaluation of micro-grid become increasingly complex. This paper focuses on the influence of demand response strategy on micro-grid's reliability. The coordination degree between the micro-grid's new energies and loads can influence micro-grid's reliability and the utilization rate of new resources. Concerning this problem, a load demand response model based on the degree to which the micro-grid's new energies satisfy the load is built. The index of the satisfaction degree is defined. Based on the time period effect of the photovoltaic generating set's contribution and the TOU electricity price strategy, a load demand response model to achieve the maximum satisfaction degree is set up, and is solved by the PSO algorithm. According to the rectified load curve and considering the micro-grid's structure as well as the energy-storage equipment's contribution strategy, a method to evaluate reliability of the grid-connected micro-grid considering demand response is established. The results of the calculation example indicate that the proposed load demand response strategy based on the degree to which the micro-grid's new energies satisfy the load can efficiently improve the reliability of micro-grid.

121 **A Novel Method for Energy Storage Sizing Based on Time and Frequency Domain Analysis**

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Energy storage is used to balance the variant power for the stability of the grid. It is significant to understand the fluctuation characteristic of renewable energy (RE) generation and the requirements of energy storage when large-scale RE is integrated in the grid. In the paper, a novel method based on time and frequency domain analysis is proposed for energy storage system (ESS) sizing, including both power sizing and energy sizing. According to the relationship between charge/discharge power and stored energy, the sizing model is established based on autocorrelation function and power spectral density (PSD) of the stochastic cycling process. The time and spectral characteristic of RE generation is analyzed based on the historical generation data of a wind farm and a PV station in the Northwest region of China. The size of energy storage is determined by the time and frequency domain method respectively. Comparing with the time domain method, it is showed that the frequency domain method is sufficient for energy storage sizing with enough accuracy and a much easier calculation process at the same time.

122 **Probabilistic Estimation of the Voltage Total Harmonic Distortion in Secondary Distribution Networks**

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Currently, there is a growing tendency of increasing in the number of nonlinear loads connected to distribution networks. This issue has concerned the electric utilities because they must ensure that any effect of harmonics on equipment and system operation does not

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compromise the quality of the electric power supply. This paper has as objective to propose a methodology to estimate the voltage harmonic distortion level in the secondary distribution networks considering uncertainties associated with the random behaviour of the nonlinear loads. The methodology is based on the combination of two techniques: three-phase harmonic power flow via current summation method and the point estimate method The results in a European distribution network with 906 nodes demonstrated that the method is very accurate to estimate the total voltage harmonic distortion. Furthermore, the proposed technique is able to identify the most vulnerable areas to harmonic problems in the secondary distribution network.

128 **The Reactive Power Optimization of Distribution Network based on Wind Power Output Scenario and Complete-bus Load**

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Dabo Zhang, Hejun Yang, Yigang He
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Giving consideration to the bidirectional uncertainty of wind power output and load, in order to improve the accuracy of reactive power optimization of asset allocation, the paper combines the wind power output scenario with complete-bus load clustering method in distribution network, and establishes the selection model of system operation scenario. This method can accurately select the system operation status, comprehensively consider the randomness of load and wind power output, and effectively configure reactive power compensation capacitor for distribution network containing wind power generators. The validity of the method is verified by IEEE 33 bus distribution system.

129 **Research on Probabilistic Reactive Power Optimization Considering the Randomness of Distribution Network**

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With the rapid development of intelligent distribution network, the uncertainty of the load and the randomness of distributed generation have brought new challenges to distribution network control operation especial in reactive power optimization. This paper uses probabilistic power flow algorithm based on three-point estimate method to solve the uncertainty caused by power flow calculation in the stochastic models of load and wind power so as to propose a method of information entropy principle to measure the voltage fluctuation. On the basis of this method, a model of probabilistic reactive power optimization considering minimum network loss and voltage fluctuation is built. Taking the IEEE 33 nodes system which contains wind power generation as an example and we draw a conclusion that if we add the minimum voltage entropy to multi-objective reactive power optimization objective function, the probability distribution of node voltage is more centralized than that of single objective reactive power optimization. Thus, to optimize reactive power by means of this model could improve the voltage stability of the system and make the voltage distribution near a certain value that

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within the scope of control in large probability. The proposed multi-objective probabilistic reactive power optimization model is suitable for the actual distribution network reactive voltage control with random properties.

130 **Reliability Evaluation Based on Equivalent Method of Sensitivity Consistency and Component Particularity Representation**

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Juan Yu, Wei Lin, Wenyuan Li, Xuan Liu
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Based on the equivalence method of sensitivity consistency and component particularity representation, an equivalent power flow model and a minimum load shedding model are proposed. With these two models, an equivalent reliability evaluation method considering the equivalence of external system is developed. Because the sensitivity information, voltage support, power support and transfer characteristics of the external network can be kept in equivalence, the power flow and minimum load shedding calculations and reliability indices for the internal network can reach higher accuracy in reliability evaluation compared to that based on other exiting equivalence methods. The simulation results on the IEEE-RTS 57-bus test system demonstrate the effectiveness of the proposed models and method.

131 **A Spare Strategy of Circuit Breakers Considering Aging Failures**

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This paper presents a spare strategy of circuit breakers (CBs) considering aging failures based on condition monitoring data. The monitoring data are used to estimate the functional ages of CBs and the aging failure rates of CBs are calculated using the functional ages. The loss-of-load damage costs caused by both repairable and aging failures of CBs are evaluated together with the investment of spares. The number and timing of spare CBs can be determined by comparing the damage cost reductions due to spares with the additional investment costs. The proposed strategy is applied to a substation located in the south China to demonstrate the effectiveness of the proposed method.

132 **Advanced Evaluation Method for Regional Wind Power Prediction**

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Accurate wind power forecast is an important method for solving the utilization problem of new energy. Forecast evaluation results have been applied to the dynamic dispatch of power systems that utilize large-scale wind power. As the starting point in optimizing regional forecast evaluation, this study first gathered fully diverse power forecast evaluation indexes that are

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based on a traditional index. Second, a comprehensive evaluation method for regional wind power forecast was proposed using principal component analysis and the information entropy calculation method. Finally, the proposed method was used to evaluate the regional wind power forecast. The case study revealed comprehensive evaluations and increased scientific weight allocation. Results confirmed the correctness and rationality of the proposed method, which can serve as a reference for power systems.

133 **Studying the Impacts of Incorporating Energy Storage Devicesinto an Aggregated Probabilistic Model of a Virtual Power Plant**

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This paper focuses on studying the changes brought about in the aggregated probabilistic representation of a distribution network containing distributed generation and local loads after the incorporation of Energy Storage Devices (ESD) into the said network. A stochastic model of the ESD is first constructed using a suitable charging/discharging strategy, and it is then combined with information about hourly generation and load for developing the overall profile of the different distribution side components, aggregated at the transmission bus level, in the form of a Virtual Power Plant (VPP). Several indices are introduced for comparing the average annual energy contributions of the VPP's constituent renewable and conventional source based generators in charging the ESDs. The VPP is modeled using a modified Roy Billinton Test System Bus 5 distribution network, and the impacts of changes in ESD related parameters like rated capacity and charging time on the introduced indices are investigated.

134 **Risk Measurement and Forewarning of Power Blackouts Based on the Entropy Theory**

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Qing He
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In this paper, the risk measurement and early warning of future power blackouts are carried out, from the angle of the lost load. Based on the entropy theory which is used to characterize the degree of power blackouts, this paper proposes a lost load forecasting model based on maximum entropy, and uses the Gansu power grid to calculate and analyze the proposed model. The example shows that the proposed model is feasible to predict the lost load. It can give a quantitative analysis of the risk of power blackouts, which can provide some useful reference for the early warning of power blackouts. On this basis, this paper proposes the lost load forecasting datas as the index to identify the critical lines that have important effects on power blackouts. The identification results show that the correctness and effectiveness of the proposed index.

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136 **Optimal Configuration of User Side Integrated Energy System Based on Chance Constrained Programming**

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A user side integrated energy system (USIES) can supply energy in accordance with user demand, in order to make full use of terminal energy conditions, improve energy efficiency, and promote consumption of local renewable energy. A bi-level programming model of USIES multi-objective coordinated planning is developed based on the chance constrained programming. Multi-state models of wind turbine (WT), photovoltaic (PV) generation and load are established respectively according to probability density functions. Then a multi-state model of the IES can be proposed. Considering economic, energy influences, environmental protection and other factors, a configuration model of USIES based on bi-level programming is established, including WT, PV, micro gas turbine and gas boiler. Annual costs is minimized in the upper level objective function in order to accomplish configuration of distributed energy sources. The optimal scheduling of micro turbine is considered in the lower level, in which objective functions include the cost of USIES losses. The elitist strategy genetic algorithm and particle swarm optimization are applied for solving the planning model. A case of USIES planning, which used is in a residential and commercial areas in the North China, verifies the effectiveness of the proposed model and method. The simulation results show that the multi-state model can simplify the difficulty of model calculation. The USIES planning based on the chance constrained programming can adequately consider the uncertainty of USIES. Under a certain confidence level, the optimal investment with the corresponding probability of the confidence level is obtained.

137 **Applying High Performance Computing to Probabilistic Convex Optimal Power Flow**

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The issue of applying high performance computing (HPC) techniques to computation-intensive probabilistic optimal power flow has not been well discussed in literature. In this paper, the probabilistic convex AC OPF based on second order cone programming (P-SOCPF) is formulated. The application of P-SOCPF is demonstrated by accounting uncertainties of loads. To estimate the distributions of nodal prices calculated from P-SOCPF, two point estimation method (2PEM) is deployed. By comparing with Monte Carlo (MC) method, the accuracy of 2PEM is proved numerically. The computation efficiency of 2PEM outperforms MC significantly. In the context of large scale estimation, we propose to apply high performance computing (HPC) to P-SOCPF. The HPC accelerated P-SOCPF is implemented in GAMS grid computing environment. A flexible parallel management algorithm is designed to assign execution threads

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to different CPUs and then collect completed solutions. Numerical results from IEEE118-bus and modified 1354 pegase case network demonstrate that grid computing is effective means to speed up large scale P-SOCPF computation. The speed up of P-SOCPF computation is approximately equal to the number of cores in the computation node.

138 **Probabilistic short-circuit analysis of wind power system based on sampling with optimal density function**

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Probabilistic short-circuit analysis (PSCA) determines vulnerability of the transmission systems. The failure uncertainty and fluctuating wind power add difficulty to PSCA. The pre-fault system states are derived by simultaneous solution to steady state constraints of power system and the doubly-fed induction generators (DFIGs). A hybrid probabilistic simulation is newly proposed, with the fault branches enumerated and probabilistically weighted, while the fault parameters sampled. The variance coefficient of hybrid Monte-Carlo (HMC) simulation is defined to describe the convergence, which is speeded up by the optimal HMC (OPHMC) with the density function of the fault types. The numerical analysis of IEEE RTS system shows the impacts of high-order fault and wind power by comparing expectation, variance, and distribution of the bus voltage and branch current. The accuracy, convergence, efficiency of Monte-Carlo (MC), HMC and OPHMC methods are compared.

140 **Spectrum Analysis Method of Residual Current Based on Hilbert-Huang Transform**

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For the development of residual current protection device in low voltage network, aiming at complexity and uncertainty of residual current spectrum in the transient process of biological electric shock faults, the Hilbert-Huang transform is applied to analyze spectrum characteristics of each intrinsic mode function (IMF) component in residual current and determine the distribution of each IMF at different time and frequency. Based on Hilbert - Huang transform, a method for characterizing the effective information of residual current signal performance is proposed. The study results show that the effective frequency in residual current is mainly below 1 KHZ and the correlation of low-frequency IMF component amplitude can be up to 0.99 above which can provide theoretical basis and technical support for the development of residual current protective device acting based on branch current signal when the human body electric shock occurs.

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141 **Composite Generation and Transmission System Reliability Assessment Using Impact Increment-based State Enumeration Method**

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An impact increment-based state enumeration (IISE) method is designed to assess reliability of composite generation and transmission systems. The reliability index calculation formula of the traditional state enumeration technique is transformed into an impact increment-based formation. Based on the derived equation, the traditional state enumeration method is modified into an impact increment based one. With the proposed method, calculation of state probability are effectively simplified, and reliability indices of high accuracy can be obtained with only low order contingency states. When it is applied to composite systems, load fluctuation can also be considered by replacing impact increments with their expectations under various load levels. Case studies are performed on the RBTS system and the RTS-79 system. Results indicate that annual reliability indices can be efficiently obtained with the IISE method. Comparing with traditional state enumeration and Monte Carlo simulation methods, the proposed method is more precise and efficient.

142 **Research on Online Monitoring and State Diagnosis of Battery for Distribution Automation**

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Batteries have been generally adopted as energy storage component at distribution automation terminal, however bad operating environment have a great impact on the performance and service life, which is very difficult for operation and maintenance of batteries. Online monitoring and state diagnosis technology is developed, through acquisition battery real time voltage, current and temperature, use of the existing communication network of distribution automation (such as optical fiber, wireless and so on) uploaded to the battery online monitoring and state diagnosis platform; battery state diagnosis model is established using neural network based on the Unscented Kalman filter (UKF), which through battery voltage, current and temperature estimation of SOC real time value; an reasonable plan is given by online monitoring and state diagnosis platform according to SOC real time value, which provide technical basis for state-based maintenance of battery.

Paper ID	Title, Author(s), Affiliation, Abstract

146 **The Use of Markov Chain Method to Determine Spare Transformer Number with 3-Criteria Parameters**

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System failure cannot be avoided, one of the solutions to maintain system reliability is with the existence of spare equipment, and however the number of spare equipment will increase the investment costs. Currently, spare transformer calculation study only considers one criteria in state transition model, a new model which considers other criteria such as transformer condition and transformer loading is needed. Java Bali 500/150 kV Transformer case study was used in order to show the usefulness of the proposed model.

147 **A Multi-state Model for the Adequacy Assessment of an Autonomous Microgrid Based on Universal Generating Function**

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With the increasing penetration of renewable energy, the uncertainty of the natural resources such as wind and solar power will affect the reliable operating of an autonomous microgrid. Based on the universal generating function (UGF) method, this paper introduced a multi-state probability model used for adequacy assessment of an autonomous microgrid and also proposed a calculation methodology of two prevailing reliability indices including loss of load probability and expected energy not supplied. The introduced multi-state models are used to capture the uncertainty of wind speed and ground illumination intensity, and of random failure characteristics of the mechanical hardware of a wind turbine and a photovoltaic system. In view of the combination explosion shortcoming of the UGF dealing with large-dimensional multi-state space, a collecting like-item technique combined with the apportionment method are utilized to reduce the amount of states and the computational burden. The proposed models are applied to a microgrid test system, based on which are investigated the impacts of the mechanical failure of components considering the topology of wind turbine and photovoltaic system, and also the configuration of installed capacity of renewable energy on the values of two indices. This simulation results can provide valuable reference for planning, designing or operating an autonomous microgrid system.

148 **Modeling of Operational Availability of Offshore Wind Turbines**

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Availability of offshore wind turbines is known as a key element to a profitable offshore wind project. Because of the poor accessibility, maintenance of offshore wind turbines dominates the availability problem. This paper presents a mathematical model for the operational availability of offshore wind turbines considering the maintenance issue and the offshore

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weather conditions. The model categorizes all the main issues varying the maintainability and then the outage time into several items that can be easily collected. The insufficiency of transfer vessels and the average operational availability of offshore WTs in a lager offshore wind farm are discussed. An example based on an offshore wind farm is used to demonstrate the application of the model. The results are compared and discussed with the field data. Sensitivity analysis forms the suggestion to allocate one vessel for every 15-20 offshore WTs in an offshore wind farm for the routine maintenance. It also provides some suggestions for the spare part management.

150 **Probabilistic-Based Identification of Coherent Generators**

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This paper proposes a new probabilistic identification method of coherent generators using Monte Carlo simulation and graph modeling. The simulation generates operating states defined by component availability, demand and generation. For each state, the electrical condition is assessed using AC power flow and community detection is applied to a graph representation of the system to detect the coherent generators groups. Finally, the probability of occurrence of each coherent generators group is computed. This methodology was tested on the IEEE 118-bus test system. Results shows that the approach is computationally simple and fast, which makes it very appealing for large power systems.

151 **Condition Monitoring and Reliability Analysis of Power Systems for Underground Cavern Facilities**

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In the context of underground cavern facilities, electrical power substation is now located underground instead of the conventional aboveground. The operating environment of power system has therefore changed, which may directly degrade the heat dissipation capability of the power system. A condition monitoring and reliability analysis of power facilities for underground substations in high humidity, high temperature and salty environment is presented, which includes three subsystems: Environment Condition Monitoring System, Operation Condition Monitoring System and Reliability Condition Monitoring System. It is capable of power system real-time monitoring, analysis, protection, optimization, and forecast failures of power facilities such as transformers, power cables and induction machines. The system has been employed in underground substations located below seabed with hazardous environment.

Paper ID	Title, Author(s), Affiliation, Abstract

152 **Condition Monitoring and Reliability Analysis of Underground Transformers**

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In the context of underground cavern facilities, the electrical power substation is now located underground instead of the conventional aboveground. The operating environment of the power system has therefore changed, which may directly degrade the heat dissipation capability of the power system. Power system components such as transformers and power cables generate heat as a consequence of ohmic and magnetic losses. To ensure the safe and reliable operation of underground power systems, the online condition monitoring and reliability analysis system for cast-resin dry-type transformers was designed, test-bedded and studied in rock caverns. The proposed system includes the condition monitoring and data retrieving, prediction, early warning and alarm for management of operational status of dry-type transformers in real time. As the harsher underground operation environment will impact the durability of the key components of the underground substation, aging analysis was conducted with algorithms developed to forecast failures and estimate residual life span of the dry-type transformers.

154 **Optimal Selection of High Voltage Transmission Connected to Island Systems**

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The development of high voltage technology provides technical conditions for the transmission of offshore new energy, but it is necessary to consider the operation status of power grid when we decide the way of grid connection. This paper focuses on the stability of the system and evaluates three access form —the high voltage alternating current (HVAC), traditional direct current (DC) and flexible DC transmission. Evaluation index and evaluation system are established. The evaluation index selects indicators from three aspects of static security, transient stability and short circuit capacity. Evaluation system is based on math method. It gets the indicators' weight through the game theory and uses intuitionistic fuzzy theory combining strict fitting degree to get the optimization choice. The theoretical analysis is based on the actual island model, evaluated through BPA simulations. Simulation results are presented to validate the expected performance of the proposed evaluation method.

157 **Optimal Power Flow with Worst-case Scenarios considering Uncertainties of Loads and Renewables**

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Paper ID	Title, Author(s), Affiliation, Abstract

The growing interest on RES gives traditional power systems an opportunity to evolve towards more sustainable and environmental entities, however the viability of RES would induce stability and reliability issues in power systems. In this paper, a DC optimal power flow (OPF) algorithm considering the worst-case scenario is proposed. It accounts for uncertainties brought by loads and renewable energy sources (RES), while in the meantime the highest reliability level of the system can be achieved. By assigning selected values with largest probabilities to random variables, the probabilistic OPF formulation is converted into a set of deterministic OPF problems in which the additional auxiliary constraints are implemented to represent the uncertain influences. The proposed OPF with the worst-case scenario is applied into an IEEE 14-bus and 57-bus benchmark power system. The results in the simulation along with other OPF techniques shows the validity and robustness of the algorithm.

158 **Time-of-use Pricing in Retail Electricity Market: Step Tariff vs. Usage-based Schemes**

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With the advances of Advanced Metering Infrastructure (AMI), it is possible for power customer and utility company to adjust their consumption behaviors or schemes in order to achieve higher profits in retail electricity market. Recently, relevant research emerges from demand side management (DSM) view. Time dependent pricing has been proposed as a DSM method to influence user demands. Initial investigations have shown its advantages over the conventional time independent pricing. Nevertheless, much is unknown in how a practical and effective time dependent pricing scheme can be designed. In this paper, we combine game-theoretic approach and probabilistic analysis methods to explore the design space of time dependent pricing. In particularly, we focus on usage-based and step tariff schemes. Our findings include: step tariff scheme improves capacity utilization during high demand period and can earn higher users' surplus than that in usage-based scheme all the time.

159 **Impact of Car Arrival / Departure Patterns on EV Parking Lot Energy Storage Capacity**

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Development and implementation of electrified transportation systems, particularly those that integrate with renewable-based vehicle charging systems are supposed to continue attracting the interest of the researchers in the future. Electric utilities have to develop integrated solutions to take the advantage of the opportunities that transportation electrification offers, in

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addition to design and planning of their supply needs. In this context, storage capacity of electric vehicles (EVs) offer a new and effective distributed storage capacity for evolving power grids. It is clear that an effective storage can be achieved by aggregating the single EVs. Commercial car parks and parking lots of several public and private companies can be used for these purposes. This paper presents improved car arrival/departure patterns to asses more realistic storage capacity models for an EVPL. Real car arrival/departure data of a representative PL, provided by The Chief Management of Istanbul Car Parking Corporation is used in the studies. In addition, future car arrival/departure patterns are estimated using the available data and PL storage capacity is obtained for those future patterns.

160 **Adequacy and Safety Comprehensive Evaluation for Ultra-high Voltage AC/DC Mixed Power Grid**

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Combining actual demands for ultra-high voltage (UHV)power grid of our country electricity production, power collection, electricity transmission and distribution, functions, adequacy and reliability of different UHV power grid projection are discussed in this paper. They were discussed that differences in function and reliability of different UHV power grid structure, and the development necessity, feasibility and rationality of UHV AC/DC power grid in China. Power supply capacity adequacy and security of different power grid were discussed complementally in the aspect of system reliability. It is shown that the UHV AC/DC transmission grid with strong frame is superior relatively to meet the performance of transmission demand in China. In terms of system security complexity, cascading failure conditions and the complexity of power system blackouts were expounded. It is pointed out that the defect of power system security defense system is an important reason leading to large scale power system blackout. While constructing the UHV AC/DC power grid, it is necessary to establish a new generation of power system security monitoring system to improve the security and defense system of large-scale power grid.

161 **Impact of Spatio-Temporally Correlated Wind Generation on the Interdependent Operations of Gas and Electric Networks**

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High penetrations of intermittent renewable energy sources (RES) affect the operations of power plants whose task is the balancing of generation and demand, and may induce critical states in interdependent energy infrastructures. In this contribution, the interdependent

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electric power and gas transmission networks are assessed under an operational risk perspective for different levels of wind energy integration. This investigation is exemplified with reference to a case study of the gas and electric transmission network of Great Britain (GB). A D-vine copula is developed for producing spatio-temporally correlated wind speed time series. In contrast to multivariate models built with autoregressive techniques or one-parameter multidimensional copulas which are restricted to modelling linear dependence or one type of dependence respectively, vine copulas offer high flexibility in modelling dependence. Due to large penetrations of wind power operational constraint violations in the gas network, e.g. pressure violations or compressor shut-downs, may occur when gas-fired power plants (GFPPs) need to ramp up quickly to compensate correlated fluctuations in wind generation. Results identify that large ramp-down rates of wind generation may cause large energy-not-served (ENS) in the electric network. For high levels of wind energy integration, unfavorable combinations of ramp-up and ramp-down are a realistic starting point of failure cascades leading to high levels of demand-not-served in the electric grid and curtailments and component failures in the gas network. Failure prone components in the gas network are identified.

162 **The Use of Markov Chain Method to Determine Spare Transformer Location**

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Replacement rate value in Markov Chain Model will give significant effect to calculations results. By definition, replacement rate is the required time to install an equipment in order to return to normal condition state. Therefore, one of the solutions to maintain system reliability is an optimum location of spare transformer. Currently, spare transformer calculations study has not clearly considers the optimum location as the output, so the new method which can provide an optimum location of spare transformer is needed. Java Bali 500/150 kV Transformer case study was used in order to answer the usefulness of the proposed model.

163 **Probabilistic Analysis of the Effect of Wind Speed Variations on Power Quality of Power Systems**

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Power system probabilistic-based studies have been performed for many years and are widely accepted by researchers and utilities. Such studies are capable of considering uncertainties of power system such as random failures of equipment and uncertainties in load forecast. With the increase of the penetration of renewable energy sources to power systems, new and additional uncertainties are needed to be considered in power system analysis. This paper presents a study methodology for evaluating the effect of wind speed variations on the power quality of power systems. A Monte Carlo Simulation method is used in the studies described in

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this paper assuming wind speed follows a Weibull distribution. Power flow is performed using a commercial program.

164 **Quasi Hamilton System Stochastic Averaging and EEAC Combined Transient Stability Analysis Method**

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Transient stability analysis of stochastic power system with Monte Carlo simulations demands vast calculation tasks. A novel transient stability analysis method for stochastic power system based on quasi-Hamiltonian system stochastic averaging and EEAC combined method was proposed in this paper. Firstly, the stochastic power system was equivalent with a two-machine system. The stochastic differential algebraic equations model of the equivalent system was established. The transient energy of the corresponding Hamiltonian system was derived. The security region of the system was determined by the critical transient energy. Then, the stochastic averaging method was applied to analyze the quasi-Hamiltonian system. The averaged system and averaged equations were got. The diffusion process of the power system transient energy is studied by the diffusion equation theory. The conditional reliability function was governed by the backward Kolmogorov equation. The impacts of excitation amplitude, fault type and fault clearing time on transient stability can be investigated quantitatively. This method was applied in the four-generator and two-area system to verify its effectiveness. Simulations show that the results coincide with the Monte Carlo method well.

165 **Cumulant-based Probabilistic Load Flow Analysis of Wind Power and Electric Vehicles**

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Probabilistic Load Flow (PLF) analysis is becoming an important part of grid design, optimization and operation due to the uncertainties added to the power network from both the generation and consumption sides. A reliable, fast and robust mathematical method for such analyses is the main step in such development. The conventional deterministic Monte Carlo(MC) analysis, though simple in implementation, becomes too slow as the networks become more complex. In this study, a new Cumulant-based method is used to assess power flows. The Probability Distribution Functions (PDFs) of the load are generated in addition to the unpredictable power resources such as wind power generation or charging demand of electric cars. Furthermore, the possible correlation between input random variables is added to the analysis. Using one of the IEEE standard networks as the case study, the capabilities and reliability of the method are demonstrated.

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166 **DATP-based sequential optimization and reliability assessment for RBDO**

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Sequential optimization and reliability assessment (SORA) has been widely used in reliability-based design optimization (RBDO), but it is hindered by the unaffordable computational burden of high dimensional cases. In this work, we propose a new strategy to improve the efficiency of the SORA while performing high dimensional RBDO. The dimension-adaptive tensor-product (DATP) algorithm and hierarchical interpolation scheme are introduced to replace the complicated black-box performance function with an approximate model, where the DATP is to overcome the so-called curse of dimension and the hierarchical interpolation scheme is to save the cost of function evaluations. Moreover, the hybrid mean value (HMV) method is adopted for the reliability assessment in performance measure approach (PMA). A two dimensional example and a ten dimensional example are included to verify the computational capability of the proposed method.

167 **Power Network Accidents Risk Assessment Based on Topology Structure**

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The "Regulation on the Emergency Response, Investigation and Handling of Electric Power Security Accidents", based on load-shedding proportion, namely the Decree No.599of the State Council of the People's Republic of China, was implemented on September1st, 2011,whichproposed new more stringent requests for power system reliability and security. Combining with related regulations on the Decree No.599,in this paper a new anticipated fault sets selection method which considers influences of electromagnetic loop networks for power grid reliability are proposed, the model of load-shedding allocating among fault substations is built, the algorithm of electricity security accidents risk grade assessment is designed. On the basis of that, taking an actual power grid as an example, simulation results can reflect electricity security accidents from perspective of probability and severity and shall distinguish weaknesses of the power grid effectively.

168 **Day-ahead Generation Schedule Model with Demand Response Considering the Secure and Economic Risks of Wind Power**

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Paper ID	Title, Author(s), Affiliation, Abstract

Wind curtailment is a severe problem in wind power development in China and demand response is considered to be one of the resources that have great potential to promote the utilization of wind power. This paper proposes a new day-ahead generation schedule model with demand response scheme in the background of joint operation of wind farms and high energy consuming loads. Considering the stochastic character of wind power, risk evaluation and corresponding optimization method is applied. The objective for this model is to minimize the secure and economic risks of wind power and the cost of thermal power units comprehensively. Detailed model and evaluation method are shown in this paper. The simulation results illustrate that this model presents better performance in reducing the wind curtailment ratio and operating cost compared with the demand response model without consideration of risks of wind power.

169 **Multi-criteria Optimization of Maintenance and Replacement Strategies in Transmission Systems**

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Assets in transmission systems are maintained and replaced according to the time-based strategy. This contribution identifies the individual importance of each asset for the availability of the grid with the help of reliability calculations and improves the allocation of maintenance and replacement activities. The optimization is performed by particle swarm algorithm. It determines the intensity of the maintenance and the year of the replacement for each asset of the grid individually. By optimizing capital expenditures, operational expenditures, and the availability of the grid, this method improves the maintenance and replacement strategy with the help of Pareto optimality. At the end of the contribution, the benefits of optimized maintenance and replacement strategies are pointed out exemplarily for a part of a 220 kV grid.

170 **Power Line Online Fault Warning Method Based on Operational Reliability and Decision Tree**

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In order to achieve the grid line online fault warning, we used operational reliability theory to generate power line fault data, and then use the decision tree method to establish the relationships between pre-fault line data and the fault, and generate the corresponding fault warning rules, simulation results show that the decision tree method can effectively achieve line fault warning, which provides useful information for the operators to guarantee the security of the power system.

Paper ID	Title, Author(s), Affiliation, Abstract

171 **Probabilistic Static Voltage Stability Analysis Considering the Correlation of Wind Power**

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The uncertainties of wind power have a great influence on the static voltage stability of power systems. The effect of uncertainty and correlation of wind power on the static voltage stability is studied in this paper and the static voltage stability is analyzed on the basis of probabilistic load flow (PLF). Moreover, quasi-Monte Carlo using Sobol sequences is adopted to obtain the samples of input random variables in order to improve the efficiency of Monte Carlo simulation (MCS), and the results are compared with those obtained by simple random sampling (SRS). Besides, Nataf transform is utilized to deal with the correlation of wind power. The proposed method is tested with the IEEE 118-bus system and the simulation results present the influence of correlated input variables on static voltage stability and demonstrate the validity and accuracy of this method.

173 **Smart Meter Data Taxonomy for Demand Side Management in Smart Grids**

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Emerging Smart Grids have given rise to deployment of advanced metering infrastructure (AMI) which produces voluminous load data with respect to time. The information extracted from this data can potentially be used to design Demand Side Management (DSM) policies. The major impediment in the deployment of DSM is the lack of knowledge of individual consumers' load demand to determine target consumers for the incorporation in DSM. This paper proposes an innovative probabilistic approach to generate typical load profiles of consumers using smart meter data. The method incorporates clustering and then re-clustering the individual clusters using the k-means clustering algorithm until reliable load profiles showing true load-time characteristics of consumers are extracted. Next, the multi layered re-clustering methodology is applied to generate typical load profiles for consumers on an alternative scale by segregating them into different classes of load levels in such a way that they represent typical smart meter consumers of the population. The approach enables the utility to determine the consumers whom can be applied the DSM actions for an effective operation of a smart distribution network and to reduce the load peak and rebound effects.

174 **A Three-stage CE-IS Monte Carlo Algorithm for Highly Reliable Composite System Reliability Evaluation Based on Screening Method**

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This paper proposes an interesting three-stage algorithm targeting at highly reliable high dimension composite system reliability evaluation using Importance Sampling (IS). The central idea is at the first stage (the *Screening stage*) picking out those bottle-neck

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components which have the most main impact on composite system reliability indexes calculation. The Screening process is specially customized for composite system to adaptively achieve the recognition process once the bottleneck percentage parameter μ is set reasonably. The relative perturbation value of each component is calculated firstly as the basis of recognition progress. In one time of iterations in recognition progress, a given percentage of the exciting bottle-neck components will be removed. After some iteration, those bottle-neck components will be screened out. The remaining *Cross Entropy Optimization* and *Importance Sampling Evaluation* stages are performed only considering the distortion of those bottle-neck components' sampling parameters. Numerical tests show that the method has good estimation accuracy performance and substantial variance reduction on highly reliable high dimension system. This also verifies the existence of degeneracy phenomenon of likelihood with the increase of dimension.

176 **Setting the Maximum Import Net Transfer Capacity under Extreme RES Integration Scenarios**

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In order to reduce the curtailment of renewable generation in periods of low load, operators can limit the import net transfer capacity (NTC) of interconnections. This paper presents a probabilistic approach to support the operator in setting the maximum import NTC value in a way that the risk of curtailment remains below a pre-specified threshold. Main inputs are the probabilistic forecasts of wind power and solar PV generation, and special care is taken regarding the tails of the global margin distribution (all generation – all loads and pumping), since the accepted thresholds are generally very low. Two techniques are used for this purpose: interpolation with exponential functions and nonparametric estimation of extreme conditional quantiles using extreme value theory. The methodology is applied to five representative days, where situations ranging from high maximum NTC values to NTC=0 are addressed. Comparison of the two techniques for modeling tails is also comprised.

177 **Application of Time-Limited Ratings to Underground Cables to Enable Life Extension of Network Assets**

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Underground cables have thermal inertia that can be leveraged to tolerate loading beyond 100% of capacity for short periods of time. These short term overloads allow the calculation of time-limited ratings for cables that are routinely underutilized such as those in N-1 configurations. These ratings are often not considered as part of distribution network modelling and only sometimes applied by network operators. Recent advances in cable rating technology allow network operators to calculate time-limited ratings in real time to adapt to contingency situations on their network. This paper proposes a methodology for determining the benefits of using time-limited ratings on an 11kV ring network. A case study shows how increasing

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loadings can be mitigated by the use of time-limited ratings and how this affects the economics of operating and planning a power system, including for avoiding network reinforcement.

178 **Research on the Periodicity of Wind Power Based on the Maximum Entropy Spectrum Estimation**

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Because wind power has the natural characteristic of intermittent, fluctuation and randomness, large scale wind power will make negative influence on the safe and stable operation of power grid. So, based on the wind power actual data of a province in north China which possesses gigawatt level capacity of wind farms group, this article uses the maximum entropy spectrum estimation method to study the time and space distribution characteristics of wind power periodicity. Analysis results show that wind power periodic component will get concentrated with the improvement of wind resources, and wind power period will be larger with the augment of wind power capacity. By mining the potential rule of intermittent wind power, this article in order to play a guiding role on power prediction, optimal scheduling, etc.

179 **Reliability and Efficiency-based Energy Storage Sizing From the Aspect of System Frequency**

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A major concern for wind farm connection to power systems is large variation of power output caused by the variability and unpredictability of wind speed. For a power system with high wind power penetration, the frequency control process of conventional generators (CGs) to match load and wind power variation becomes an important operation issue. Energy storage systems play an important role in solving the problem. This paper proposes an analytical technique to select the optimal size of battery storage system (BSS) for a power system based on operational reliability analysis and frequency control process. According to optimal size of BSS, the optimal size of state of charge (SOC) and depth of discharge (DOD) are selected to achieve the minimal frequency variation for the fixed wind farm.

180 **Fatigue Reliability Analysis of Wind Turbines Shafts Caused by Sub-Synchronous Oscillations During Power System Fault**

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Fatigue and destruction in the shafts of a wind turbine caused by sub-synchronous oscillations during power system faults is critical for wind turbine reliability. This paper investigates a three-mass shaft model according to a MW class doubly-fed wind generator shaft mechanical structure and obtains the electromagnetic torque of a wind turbine by PSCAD simulation when sub-synchronous oscillation occurred in power system. The equivalent load spectrum is

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obtained via the rain flow counting method. The finite element model of the gear is set up by Solidworks software. And then it is meshed by ANSYS software and finally the equivalent Von-Mises stress is achieved. The fatigue damage of transmission gear caused by sub-synchronous torsional vibration loads was assessed through Ncode software based on the S-N theory and Miner theory, and then it carries on the analysis of reliability. To sum up, the paper provided an analysis of the fatigue damage of wind turbine shafts caused by sub-synchronous oscillations of various durations during power system faults. The results are helpful to predict the fatigue life of wind turbine gear, to better maintain wind turbine shafts in time and to improve the safety and reliability of wind power system.

181 **Failure Rate Estimation of Power Transformers Using Inspection Data**

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An approach to evaluating the failure rate of power transformers with consideration of inspection and test results is presented. Hazard plotting, a conventional statistical method, is used first to find the best model that fits the aging failure data. Then, by exploring the power transformer's Health Index correlation to age, a method is established to adjust its failure rate based on the evaluated condition. The study of failed and in service units proves the viability of the proposed method.

182 **Reliability Evaluation of Transmission System Based on Vulnerability Analysis**

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Peng Wang
Nanyang Technological University
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Reliability evaluation combines the concept of severity of the accident consequence and the likelihood of it occurring. The severity of the accident consequence caused by transmission lines malfunction has rarely been considered in the existing contingency screening technique. This paper proposed a fast contingency filtering technique for transmission system reliability evaluation based on vulnerability analysis. The influence of faulty transmission lines on the severity of accident consequence is described by functional factors based on the vulnerability analysis. The sequence of transmission lines is ordered by the severity coefficients determined by state probabilities or functional factors of the faulty lines or both of them. Contingency states are searched and ranked based on the sequence of transmission lines. Three severity coefficients for a line are defined and examined based on reliability and functional factors. The merits of the proposed techniques and severity coefficients are validated by evaluating the IEEE-RTS79 test system.

183 **Reliability Evaluation for Distribution Systems Considering Flexible Loads Utilizing Time-sequential Simulation Techniques**

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Weidong Liu, Lijun Zhang, Yikai Sun
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With the development of information and communication technologies, flexible loads have become more and more popular to participate in the two-way interaction between power generation and consumption. However, the growing proportion of flexible loads has made the reliability of smart grids different from that of traditional power systems. In this paper, time-varying load model including flexible loads has been represented by developed Markov process model. Load curtailment and shifting have been considered in the developed Markov model for flexible loads. Moreover, time-sequential simulation procedures of reliability evaluation for distribution systems considering flexible loads have been developed. The proposed techniques have been validated to the modified IEEE RBTS.

184 **Evaluating the Spatial Correlations of Multi-Area Load Forecasting Errors**

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The short-term load forecasting error highly affects the security and economic operation of power systems. The load in different areas are distinct in the composition of consumers, impact factors, and profiles, and are thus of different forecast ability. Understanding the correlations of load forecast error among different areas would provide significant insight on the ways of managing the forecast errors. This paper carries out empirical studies on the spatial correlations of multi-area short-term load forecasting errors in Guangdong Province of China. Firstly, Artificial Neural Network (ANN) algorithm is used to conduct the day ahead forecast for 21 cities. Secondly, spatial correlations between load forecasting errors are quantified by Pearson correlation and the relationship between Pearson correlation and spatial distance is studied. Finally, copula method is used to model the joint distribution of two cities' load forecasting errors. The study shows that the forecast errors of different cities have a strong correlation. The extent of correlation depends on the distance of two areas. The joint distribution of the forecast error between cities can be effectively modelled by Gaussian Copula.

185 **Power System Risk Assessment Method Based on Dynamic Power Flow**

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Lin Cheng
Tsinghua University
Beijing, China

Risk assessment theory is paid more and more attention to consider the random characteristics of power system, but traditional method could not consider the operating factors as frequency response of generators and loads, various emergency control measures. In this paper, a dynamic contingency analysis method base on dynamic load flow is proposed considering the above factors. The dynamic contingency analysis is a less time-consuming approach, but could simulate as well the detailed load shedding relay model, and the time-varying reliability model. So the proposed dynamic contingency analysis gives a good tool for cascading failure simulation.

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187 **Probabilistic Short-term Wind Power Forecasting Based on Deep Neural Networks**

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High-precision wind power forecasting is an essential operation issue of power systems integrated with large numbers of wind farms. In addition to traditional forecasting methods, probabilistic forecasting is recognized as an optimal forecasting solution since it provides a wealth of valuable uncertainty information of wind power. In this paper, a novel approach based on deep neural networks (DNNs) for the deterministic short-term wind power forecasting of wind farms is proposed. DNN models including long short-term memory (LSTM) recurrent neural networks (RNNs) have achieved better results compared with traditional methods. Further, probabilistic forecasting based on conditional error analysis is also implemented. Favorable results of probabilistic forecasting are achieved owing to elaborate division of the conditions set based on cluster analysis. The performance of the proposed method is tested on a dataset of several wind farms in north-east China. Forecasting results are evaluated using different indices, which proves the effectiveness of the proposed method.

188 **Wind Power Correction Method Including Multiple Factors Such as Wind-Abandon Coefficient**

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Wind power forecast plays an important role in wind farm operation and grid scheduling decisions. Prediction of power output from wind vector based on wind farm equivalent power curve is the final step of forecast, which has a lot of interaction with the grid dispatching, and it has a particularly prominent influence on the wind farm power output so as to cut down prediction accuracy. Focusing on the step of "wind-power transformation", a correction method of day-ahead wind power forecast including multiple factors such as wind-abandon coefficient is proposed in this paper. Firstly, it is proved that the wind power prediction error is affected by a variety of factors, such as the amplitude of predicted power, the volatility of forecast as well as the stability of recent wind power output. And a model is built to quantify them respectively. Then the wind-abandon coefficient is introduced to modeling the effect of wind power curtailment activities of grid dispatching to forecast accuracy. Finally, the evaluation model of wind power forecasting error is built by using the multiple linear regression method and corrects the predictive value. Case study basing on the actual operation data of a wind farm in northern China has shown that the proposed method is effective to improve the accuracy level of wind power forecast.

189 **Overhead Line Weak Point Mechanical Analysis Based on Markov Chain Method**

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In this work, a concept for overhead power line weak point analysis based on the calculation of minimal clearance to ground is presented. Line temperature should be known before

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mechanical calculations are performed. For that purpose IEEE 738 Std. was taken. Calculation accuracy was previously verified by authors with real line parameters and described in the paper. To calculate thermal behavior of conductor, several parameters should be known, such as wind speed, wind direction and ambient weather temperature. These data were artificially generated from three weather stations ten years' time series located near to the line. To acquire the data on line, the interpolation geostatistical toolbox was used. Several line weak points were revealed. Line weak point position can be used as an area where monitoring equipment for dynamic line rating should be installed when the transmission system operator has an economical restriction, and it is impossible to have multiple areas for DLR equipment installation.

190 **Long-Term Spanish Electricity Market Price Forecasting with Cointegration and VEC Models**

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Commodity and electricity price models are motivated by the several unexpected evolutions that commodity prices have shown over the previous decades. Several models are based on the classic Black-Scholes model, which was one of the first to simulate the stochastic behaviour of commodity prices. However, as of today, these forecasting models show poor performance when tested in long-term horizons, especially when applied to electricity market prices. This work attempts to determine a way to provide a decent accuracy in long-term (one year or more) forecasts of the Spanish electricity market price using cointegration and vector error correction (VEC) models, alongside other variables, such as fuel spot prices and futures prices. These variables have been assessed in order to determine which factors contribute to this work's purpose.

191 **An Agent Based Model of a Frequency Activated Electricity Reserve Market**

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This paper introduces an agent based model for Frequency Activated Reserve Markets. Generation Units (GenUns) bid both prices and quantity in interconnected and dynamically congested Market Areas in order to reach their optimal production point. The units are limited by their spare capacity after their actions on the spot market. Generation Companies (GenCos) manage the strategy portfolios of their subordinate agents with the goal of coordinating the bidding behavior and subsequently increasing profits. A case study of Monte Carlo simulated units will show the dominance of Marginal Cost bidding over different periods and pricing modes (System Price and Pay-as-Bid) as well as the quality of the chosen modeling approach.

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192 **The Stability Analysis and New Torque Control Strategy of Direct-Driven PMSG Wind Turbines**

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This paper expounds on the direct-driven PMSG (permanent magnet synchronous generator) wind power system control strategy, and analyses the stability conditions of the system. The direct-driven PMSG wind power system may generate the intense mechanical vibration, when wind speed changes dramatically. This paper proposes a new type of torque control strategy, which increases the system damping effectively, mitigates mechanical vibration of the system, and enhances the stability conditions of the system. The simulation results verifies the reliability of the new torque control strategy.

193 **VSC's Reactive Power Limited Probabilistic Power Flow for AC/DC Grids Incorporating Uncertainties**

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Gansu, China

The speed of Probabilistic Power Flow (PPF) analysis for hybrid AC/DC grids (ACDCPPF) can be significantly decreased if the corresponding adjustment strategy of Voltage Source Converter (VSC) on the reactive power is not properly designed. To address this issue, a new strategy on the reactive power adjustment of VSC is proposed. A Monte Carlo Simulation (MCS) method is used to model uncertainties in the stochastic behaviors of Photovoltaic (PV) stations and loads. The feasibility and the effectiveness of the improved ACDCPPF are validated using a modified IEEE 9-Bus test system. The simulation results indicate that with the proposed adjustment strategy and the empirical optimal value, the number of AC/DC alternate iterations in a VSC's reactive power limited AC/DC system can be greatly reduced in each sampled Deterministic Power Flow (DPF), which leads to a significant improvement in the computing speed of the ACDCPPF analysis.

194 **Reliability Assessment of AC Distribution Network with Multi-terminal DC Interconnection**

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Fulong Song, Yi Gao, Ying Wang
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The distribution system operation in Beijing, China, is investigating on an AC/DC topology for expanding a local distribution system. The feature is to install multi-terminal DC interconnections (MTDI) among three substations, in order to achieve un-interrupted load transfer as well as better loading sharing during primary transformer N-1 outages. This paper presents a reliability assessment of hybrid AC/DC distribution network with the multi-terminal DC interconnection (MTDI). This paper consists of two major parts, which are a reliability

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model of the MTDI and a power supply restoration scheme. Case studies are performed through a real-life distribution network. The results suggest that reliability of the distribution network can be improved and the capacity of the transformer can be reduced with the joint of MDCI.

195 **Reliability Assessment of Multiple-Voltage Regional Transmission and Distribution System Considering Substation Interior Failure**

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With the increase of load density and the high request of supply reliability, voltage level of urban power grids is continuously rising. 220 kV has been popular in cities and even 500 kV substations have been directly located in urban area. Multiple voltage levels coexist in a rather small area, forming a meshed transmission and distribution network in urban region. So traditional distribution system reliability evaluation approaches can barely satisfy the requirements of reliability evaluation in urban power grid planning and operation. A reliability assessment approach for multiple-voltage regional systems based on reliability equivalent law of series system is proposed. An equivalent model of substation bus system has been introduced, considering simultaneous outage of multiple feeders and common mode failure (CMF) inside substations, which incorporates the effect of substation failures on the reliability of the network. This method has been applied on a typical urban grid in China with medium- and high-voltage distribution network. Simulation results have proven the effectiveness and advantages of this method, which can act as an aid in decision making for urban grid planning and design.

196 **Forecast uncertainty modeling and Data Management for a cutting-edgeSecurity Assessment platform**

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The increasing penetration of renewables and the constraints posed by pan-European market make more and more crucial the need to evaluate the dynamic behaviour of the whole grid and to cope with forecast uncertainties from operational planning to online environment. The FP7 EU project iTesla addresses these needs and encompasses several major objectives, including the definition of a platform architecture, a dynamic data structure, and dynamic model validation. The on line security assessment is characterised by a multi-stage filtering process: this includes a "Monte Carlo like approach" which applies the security rules derived from extensive security analyses performed offline to a set of "new base cases" sampled around the power system (PS) forecast state with the aim to discard as many stable contingencies as possible. The paper will focus on the management of historical data -related to stochastic renewable and load snapshots and forecasts- in order to solve some intrinsic criticalities of raw data and to derive a reliable model of the multivariate distributions of renewables and loads

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conditioned to the specific forecast state of the grid, with the final aim to generate the "uncertainty region" of states around the forecast state.

197 **Net Transfer Capacity Assessment Using Point Estimate Method for Probabilistic Power Flow**

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Nowadays the management of interconnected transmission systems requires security assessment methods able to consider uncertainties due to the increasing presence of renewable generation. Furthermore, also the electrical demand is characterized by a certain level of variability which affects the accuracy of the expected consumption profiles. Thus, probabilistic approaches are an interesting research field to improve reliability of operational planning on future power systems. This work proposes a probabilistic methodology for the evaluation of the Net Transfer Capacity (NTC) between interconnected power grids. The method considers the forecast uncertainties on renewable generation and load consumption, by exploiting the Point Estimate Method (PEM) coupled with Third-order Polynomial Normal Transformation (TPNT). The proposed procedure is applied on a benchmark IEEE test system and validated through comparison with a conventional technique.

198 **Online Security Assessment with Load and Renewable Generation Uncertainty: the iTesla Project Approach**

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The secure integration of renewable generation into modern power systems requires an appropriate assessment of the security of the system in real-time. The uncertainty associated with renewable power makes it impossible to tackle this problem via a brute-force approach, i.e. it is not possible to run detailed online static or dynamic simulations for all possible security problems and realizations of load and renewable power. Intelligent approaches for online security assessment with forecast uncertainty modeling are being sought to better handle contingency events. This paper reports the platform developed within the iTesla project for online static and dynamic security assessment. This innovative and open-source computational platform is composed of several modules such as detailed static and dynamic simulation, machine learning, forecast uncertainty representation and optimization tools to not only filter contingencies but also to provide the best control actions to avoid possible unsecure situations. Based on High Performance Computing (HPC), the iTesla platform was tested in the French

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network for a specific security problem: overload of transmission circuits. The results obtained show that forecast uncertainty representation is of the utmost importance, since from apparently secure forecast network states, it is possible to obtain unsecure situations that need to be tackled in advance by the system operator.

199 **Reviewon Power System Cascading Failure Thoeries and Studies**

Xiaohui Ye, Wuzhi Zhong, Xinli Song, Guoyang Wu, Tao Liu, Zhida Su
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A large number of blackouts have happened in power system recently, and most of them are cascading outages. Because of their severe consequences, a variety of methods are proposed to study the mechanism of cascading outages. These methods can be divided into four categories: self-organized critical theory, complex network theory, operational reliability theory, and power system simulation theory. This article reviewed the researches on cascading outages, and pointed out some important research achievements and their drawbacks.

200 **A heuristic for the synthesis of credible operating states in the presence of renewable energy sources**

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Experience has shown the limitations of deterministic criteria when accommodating the intrinsic uncertainties associated to modern power systems. Hereof, probabilistic risk assessment represent a powerful enhancement in order to ensure the overall power system reliability rather than a worst-case scenario analysis. This paper presents a general-purpose methodology intended to generate plausible operating states. The main focus lies on the generation of correlated random samples using a heuristic of the NORmal-to-Anything (NORTA) method. The proposed methodology was applied to model wind generation in the Danish Western power system, analyzing the effect of the marginal distributions and errors in the correlation matrix definition.

201 **The Anomalous Data Identification Study of Reactive Power Optimization System Based on Big Data**

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Huanna Niu, Yuzhu Wang, Jingxiang Zhao
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With the continuous development of smart grid and energy Internet, modern power system is gradually evolved into the one with funnel large amounts of data and calculation of large information systems, which shows the applicability and feasibility of the analysis technology of data mining. This paper puts forward a big data modeling method for the reactive power optimization based on the theory of the large dimensional random matrix. On the basis of it, large dimensional random matrix is disposed, applied with higher dimensional random matrix theory related to the characteristics of abnormal data detection, for judging the existence of

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abnormal data. If existed, this matrix is used in accordance with Pauta criterion identification to find the abnormal data. At the end of the article, it is verified by analysis examples of its effectiveness and applicability.

202 **Stochastic Generator Availability Modeling on Very Large Transmission Network Systems**

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This paper examines the possibility of performing nodal level loss of load analyses using a full stochastic optimization Monte Carlo modeling tool on a transmission network the size of MISO system.

203 **Wind Power Curtailment Evaluation Based on EOF and Hierarchical Clustering Method**

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Zhengpai Cui, Rongfu Sun
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Wind power curtailment has greatly hindered the development of wind power industry in China. The accurate evaluation of wind power curtailment is vital for the economic dispatch and secure operation of power systems integrated with wind power. Benchmarkingwind turbine method has been commonly used for wind power curtailment evaluation in China since 2013. An improved evaluation method of wind power curtailment based on EOF and hierarchical clustering method is proposed in this paper. The method obtains the theoretical generation of wind farms by multiplying the output of selected one or several wind turbines and the total number of wind turbines with certain allocation coefficients. The selection of benchmarking wind turbines and the determination of allocation coefficients are important issues. Wind turbines are divided into groups according to the spatial distribution characteristic of wind resource inside the wind farm. The clustering result is used for selecting sample wind turbines and determining allocation coefficients, applied to the estimation of wind power curtailment. Finally, the case study illustrates that the proposed method is effective with comparison of conventional benchmarking wind turbine method based on one-year observed data.

204 **Supply Interruptions and Voltage Dips in Smart Distribution Systems with Feeder Automation and Reconfiguration**

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This paper analyses the impact of smart grid (SG) automation and reconfiguration functionalities on supply interruptions and voltage dips due to faults in medium voltage (MV)distribution systems. The analysis is illustrated using feeder automation and reconfiguration techniques adopted in Italy for fault detection and isolation, with reference to a simple MV homogeneous and symmetrical test network. The effects of temporary and

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permanent faults of different types and at different fault locations are evaluated in terms of changes of supply voltage, i.e. duration of long interruptions (LIs) and short interruption (SIs) and magnitude and duration of voltage dips (VDs), for different switching time sequences of the specific automation and reconfiguration techniques adopted. Afterwards, models of grid, automation systems, nodes and whole system are developed to allow for a more detailed and accurate evaluation of LIs, SIs and VDs, Finally, numerical analyses aimed to evaluate LI, SI and VD indices for the different automation techniques are performed and comparisons in terms of some reliability indices are reported.

205 **Reliability-Centered Asset Management Using Component Reliability Importance**

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Asset management is an important topic in all fields especially in power system which has very high investment costs and very expensive elements. Reliability Centered Asset Management (RCAM) is an effective technique to perform the power system asset management with quantitative methods such that, on the one hand, the total cost is minimized and, on the other hand, the reliability of the system is maximized. Nevertheless, the need for an appropriate optimization-based algorithm for RCAM implementation in power system is still sensed. This paper proposes an algorithm to fulfil such needs including the following steps. First, the component reliability importance index is calculated for all components of the system. Then, a set of all potential maintenance strategies of each component are defined and together with the component reliability importance indices are used as inputs in the third step. In the third step, an optimization problem is proposed to select the optimum maintenance strategy for each component in the system. The proposed three-step algorithm is tested on a Swedish distribution system. The results highlight the advantages of the proposed method for well-organizing the maintenance strategies for all components of the system.

209 **Overvoltage Risk Analysis in Distribution Networks with High Penetration of PVs**

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Solar power has become one of the mainstream distributed renewable energy sources due to its clean and renewable feature and the global push for renewable energy. In a distribution network with high penetration of photovoltaics (PVs), overvoltage is a common and major issue that needs to be addressed to assure system reliability and security. Increasing interests have been given to real time operation of PVs to fully utilize PV generation capacity while the voltage is regulated within a proper range. However, little research has been done on exploring the overvoltage risk at the planning phase. This paper proposes a probabilistic method to evaluate the overvoltage risk in a distribution network with different PV capacity sizes under different load levels. Kolmogorov–Smirnov test (K–S test) is used to identify the most proper probability distributions for solar irradiance in different months. To increase accuracy, an

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iterative process is used to obtain the maximum allowable injection of active power from PVs. The effectiveness of proposed method is verified on a 33-bus system.

211 **Application of Non-Intrusive Polynomial Chaos Expansion in Probabilistic Power Flow with Truncated Random Variables**

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In this paper, the authors apply a surrogate model-based method for probabilistic power flow (PPF) in the power system subject to truncated random variables. Due to a growing number of uncertainty sources are being brought into the modern power system, the traditional deterministic power flow analysis lacks its ability to recognize the realistic states of power systems, and thus turns to PPF for help. However, the PPF analysis is still facing several challenges: the computational effort required by the traditional simulation method is prohibitively expensive; and the modeling of uncertainty sources needs the improvement on both distribution type selection and parameter evaluation. The novelty of this work lies in taking advantage of both general polynomial chaos (gPC) expansion and ordinary least squares (OLS) to deal with PPF in presence of the truncated random variables. The performance of the proposed method is verified on the IEEE 30-Bus test system, considering uncertain factors brought by active power at load buses. In different test scenarios, the proposed method shows sound performances at the cost of less computational effort, compared to the traditional approach.

213 **Impact of Wind and Solar Variability on the Resource Adequacy for North American Bulk Power System**

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The goal of bulk power system planning is to ensure that sufficient energy resources and electric transmission infrastructure are installed to serve demand. System planners use forecasts of future demand along with existing and planned resources to determine, on a probabilistic basis, if those resources will be sufficient in meeting reliability targets. Several identified trends within North American Electric Reliability Corporation (NERC) Assessment Areas for the North American Bulk Power System (BPS)are showing tightening Reserve Margins year-to-year from previous assessments. These trends, combined with the ongoing changes to future generation portfolios and load conditions, create uncertainties and potential reliability risks to the BPS. This paper addresses the uncertain performance of Variable Energy Resources (VER), such as wind and solar, and provides stochastic models that have been incorporated into the Electric Reliability Council of Texas (ERCOT) interconnected system. Wind and solar capacity factors, using a time series method, are presented as well as a Monte Carlo simulation that has been carried out to show the impact of uncertain parameters affecting Reserve Margin calculations. Lastly, a probabilistic sensitivity analysis has been

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performed; these results are presented by parameter significance.

214 **Impact of Network Topology Optimization on Power System Reliability**

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Due to the increasing power demand and the aging equipment, the electric power grid is faced with pressing challenges for maintaining its power supply reliability in an efficient and economical manner. Network topology optimization (NTO) is a promising, cost-effective method to improve the operational flexibility and the overall reliability of power systems. In this study, NTO is incorporated into the conventional reliability evaluation framework, and case studies are conducted based on a representative reliability test system. The simulation results demonstrate that the overall power system reliability could be improved assuming NTO is incorporated into the power system operation procedure. This study could offer some insights into improving power supply reliability by more fully utilizing the existing assets in a power system.

216 **An Optimum Regression Approach for Analyzing Weather Influence on the Energy Consumption**

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In the modern society, energy consumption such as gas and electricity is closely related to the weather condition because of the large share of weather-sensitive electrical appliances. Investigating how weather influences the energy consumption is of great significance for energy demand forecasting. This paper proposes an optimum regression approach for analyzing weather influence on the energy consumption. It combines several regression algorithms such as Artificial Neural Network (ANN) and Support Vector Machine (SVM) with optimum weights. The weights of these regression algorithms are determined by formulation of an optimization model considering their corresponding fitting errors. Case studies on two international competitions on energy consumption forecasting are conducted. One is the 2015 Npower Forecasting Challenge, which focuses mainly on the gas consumption; the other one is the 2016 BigDEAL Forecasting Competition, which puts more attention on electrical load forecasting of a certain area. The proposed algorithm was ranked Top 2 in both competitions. It verifies the effectiveness and superiority of our proposed method.

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217 **Reliability Evaluation of Active Distribution Systems Considering Energy Storage and Real-Time Electricity Pricing**

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Due to the increasing integration of renewable resources and the deployment of energy storage units at the power distribution level, conventional deterministic approaches may not be suitable or effective for evaluating the reliability of active distribution networks anymore. This paper proposes a new method to evaluate the active distribution system reliability including microgrid and energy storage. The power output of distributed generator (DG) within the microgrid is first calculated based on the approach of generalized capacity outage tables (GCOTs).Then Monte Carlo Simulation (MCS) is utilized for performing power system reliability evaluation. The results obtained considering different energy storage capacities are compared. Furthermore, real-time pricing (RTP) strategy is considered in optimizing the control strategy of the energy storage device and the corresponding reliability indices are recalculated.

218 **Probabilistic power flow considering variable bandwidth kernel density estimation for traction substation loads of high-speed railways**

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A probabilistic power flow method considering variable bandwidth kernel density estimation (VKDE) for traction substation loads of high-speed railways is proposed. A variable bandwidth kernel density estimator, which varies the bandwidths to minimize mean squared errors at different estimation points, is adopted to model traction substation loads of high-speed railways. The traction substation loads are sampled by acceptance-rejection method for Monte Carlo probabilistic power flow calculation so that the effects of traction substation loads on power system operation can be effectively analyzed. The effectiveness of the proposed method is illustrated by simulations of practical traction substation loads and the modified IEEE 14-bus system.

219 **A Comparative View of Risk Management in Financial Sector and in Next Generation Power Grid Operation**

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This article offers a comparative view of applied risk management in market-based operation of the next generation power grid, based on the principles and lessons of risk management developed in the financial sector. It argues that the dual signatures of public and private goods on electricity products and services in wholesale power markets are the roots of many

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fundamental challenges including risk management, and due to the symbiotic public and private goods properties of electricity products, the general risk management framework should be more appropriate to support the decisions under uncertainty, instead of the classic ones for complete market environments. Further, we overview the subjective and objective aspects of risk management followed by explanation of three managing philosophies concerning ontological attitude. Based on the conceptual discussions, we show the importance of in-depth understanding of characteristics of the next generation power grid to risk management. In addition, the unique features of risk analysis in power system and market operations are discussed, comparing to those in the financial sector. Finally, some lessons learned from practices in financial sectors as well as the challenges to the power industry are summarized.

220 **A New Approach for Frequency Based Short-term Reliability for a Power System**

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In this work, we provide a completely new approach for a short-term power system reliability that can be utilized for systemoperation planning. The proposed index incorporates the system frequency as a reliability of the grid and its deviation over a short time period. Although frequency performance is often employed as a quality metric for the past system operation, our model can address the future system condition by forecasting the statistics of the system frequency for a specific operation condition. In our model, demand, renewable source, battery and generators are stochastically incorporated. Using the equilibrium of demand and supply, and the physical constraints of automatic generation control (AGC), a model is developed, from which the system frequency distribution is obtained. From the contrived system frequency, statistical function, referred to herein as Frequency Reliability Distribution Function (FRDF), is proposed from which various criteria could be developed for short-term reliability. The developed FRDF along with the pertaining metrics are utilized for some case studies with IEEE reliability test system.

221 **Probabilistic assessment of a distribution tariff scheme for incentivizing demand side management in the small energy usage sector**

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Lately distribution utilities worldwide have been incentivized to reduce operating expenses that have severely increased with the integration of distributed generation. Enabling demand flexibility in the low voltage network seems a promising means at this direction. Given the current (low) electricity prices and the stochasticity of distributed generation and loads, this paper explores whether a capacity-based distribution tariff that rewards low power withdrawal during peak hours could incentivize small end-users to participate in demand side management. The assessment deploys a pseudo-sequential Monte Carlo simulation that uses

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quarter-hourly energy measurements and accounts for network constraint management. The presented case study highlights that a coordinated technical implementation is required, both during peak and non-peak periods, for not stressing LV network operation with the integration of flexibility. The potentially generated revenue for end-users, thanks to their response to the considered distribution tariff, results sufficiently motivating for engaging them in flexibility actions.

222 **Volatility in Electrical Load Forecasting for Long-term Horizon – An ARIMA-GARCH Approach**

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Electrical load forecasting in long-term horizon of power systems plays an important role for system planning and development. Load forecast in long-term horizon is represented as time-series. Thus, it is important to check the effect of volatility in the forecasted load time-series. In short, volatility in long-term horizon affects four main actions: risk management, long-term actions, reliability, and bets on future volatility. To check the effect of volatility in load series, this paper presents a univariate time series-based load forecasting technique for long-term horizon based on data corresponding to a U.S. independent system operator. The study employs ARIMA technique to forecast electrical load, and also the analyzes the ARCH and GARCH effects on the residual time-series.

223 **A Multistage MILP-Based Model for Integration of Remote Control Switch into Distribution Networks**

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In the past decades, remote control switches have been broadly integrated into distribution systems to achieve a certain level of service reliability. To take utmost benefits of them, a cost-benefit analysis should be conducted. In this regard, the budget restriction plays a crucial role in remote control switch placement. This paper is aimed at proposing a model to determine the optimal number and location of remote control switches in a distribution system. As the main contribution of the paper, the model is developed in multistage planning format to address the issue of budget limitation. To this end, the model is formulated in mixed integer linear programming format, which tries to minimize the total interruption costs in conjunction with capital investment, installation, and maintenance costs of remote control switches. The effectiveness and applicability of the proposed model is thoroughly examined through a test system. Resultant findings show the importance of considering multistage-based switch placement problem to cast the budget limitation in hand in an efficient way.

Paper ID	Title, Author(s), Affiliation, Abstract

225 **Capacity Credit and Reasonable ESS Evaluation of Power System including WTGs combined with BESS**

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This paper proposes a new method for evaluating Effective Load Carrying Capability(ELCC) and Capacity Credit(C.C.) of power system including Wind Turbine Generator(WTG) combined with Battery Energy Storage System(BESS). WTG can only generate electricity power when the fuel(wind) is available. Because of fluctuation of wind speed, WTG generates intermittent power. In view point of reliability of power system, intermittent power of WTG is similar with probabilistic characteristics based on power on-off due to mechanical availability of conventional generator. Therefore, high penetration of WTG will occur difficulties in power operation. The high penetration of numerous and large capacity WTG can make risk to power system adequacy, quality and stability. Therefore, the penetration of WTG is limited in the world. This study develops a new method to assess how much is penetration of WTG able to extended when WTG is combined with BESS. This paper demonstrates a various case studies of ELCC and C.C. of power system containing WTG combined with BESS using model system as similar as Korea power system.

226 **Uncertainty quantification in power system reliability using a Bayesian framework**

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Long-term generation investment(LTGI) models have been widely used as a decision-making tool of design of energy policy. Adequate LTGI models with detailed modelling of operations are often computationally intensive. Uncertainty involved in these models poses a great challenge to the uncertainty quantification in power system reliability. This paper presents a Bayesian framework for addressing this challenge systematically. The use of Bayesian techniques enables an efficient model calibration and quantitative study on the robustness of different market designs. In the case study on the future UK power system, the robustness index estimated by the calibrated model is obtained through uncertainty analysis of loss-of-load expectation.

227 **Optimal Coupling of Heat and Electricity Systems: A Stochastic Hierarchical Approach**

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The large penetration of renewables in the power system increases the need for flexibility. Flexibility gains and wind curtailment reduction can be achieved through a better coordination with other energy systems, in particular with district heating. Loose interactions between these two systems already exist due to the participation of CHPs in both markets. New market structures must be developed in order to exploit these synergies. Recognizing the

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above-mentioned challenges this paper proposes a stochastic hierarchical formulation of the heat economic dispatch problem in a system with high penetration of CHPs and wind. The objective of this optimization problem is to minimize the heat production cost, subject to constraints describing day-ahead electricity market clearing scenarios. Uncertainties concerning wind power production, electricity demand and rival participants offers are efficiently modelled using a finite set of scenarios. This model takes advantage of existing market structures and provides a decision-making tool for heat system operators. The proposed model is implemented in a case study and results are discussed to show the benefits and applicability of this approach.

228 **User Friendly Generator Maintenance Scheduling Simulation System based on Probabilistic Methodology**

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This study develops alternative user friendly generator maintenance scheduling(GMS) considering not only probabilistic reliability maximization but also probabilistic production cost minimization. Furthermore, the proposed GMS system has various kinds of objective functions as like as CO2 minimization. The probabilistic reliability objective includes LOLE(Loss of load expectation), EENS(Expected energy not served) and EIR(Energy index of reliability). Production cost is evaluated with consideration of uncertainties of generators. In actual system case study describes effectiveness and user friendly of generator maintenance scheduling simulation systems proposed in this paper. Additionally, the practicality and effectiveness of the proposed approach are demonstrated in the simulation for a real-size power system model in Korea South-East Power CO.(KOEN).

229 **Discrete forecast error scenarios methodology for grid reliabitity assessment in short-term planning**

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With the increasing amount of renewable and difficult-to-forecast generation units, Transmission System Operators (TSO) are facing new challenges to operate the grid properly. Indeed, given the intrinsic variability and limited predictability of most renewable generations, the application of the conventional and deterministic N-1 method becomes very costly. Therefore, a new approach is needed for system operational planning. This paper presents a method that combines the advantages of probabilistic and deterministic approaches in order to estimate risk indicators while considering errors on weather (hence generation) forecasts, uncertainties on loads and timing constraints of the decision-making process in operational planning. This decision support method provides the planner with indicators to analyze, improve and finally, validate a grid plan. The method has been tested and its results have been compared with the classical N-1 analysis. Results show that the method offers more indicators to help the planner and to compare different grid plans.

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230 **House Events Matrix for Shutdown Probabilistic Safety Assessment**

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Probabilistic safety assessment is one of the standardized ways of assessing safety of nuclear power plants. The objective of the method is to present an extension of the fault tree in order to reduce the size of the shutdown probabilistic safety assessment model. The shutdown probabilistic safety assessment method is developed. The modelling for all plant operating states include consideration of 15 states, which were determined as appropriate representations of much more plant configurations in addition to the plant full power operation. For dealing with the complexity of the models and manageable size of the models for the sensitivity studies it is essential that the models optimizations are performed. House events matrix plays an important role as it reduces the number of the fault trees significantly. The results include the time dependent representation of the core damage frequency contributions weighted for their plant operating state durations over total duration of the shutdown timely through the whole shutdown. The risk of the plant during shutdown is smaller in general than in full power operation, however for certain specific plants and their specific plant operating states the risk for a short duration of time may increase beyond the risk of full steady state power operation.

231 **Zonal operating reserve demand curve applied to day-ahead deterministic unit commitment**

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The timing and the locational values of operating reserves(ORs) need to be rewarded to improve reserve deliverability and adequate incentive for flexible generating resources in a transmission network. An enhanced deterministic unit commitment model incorporated with hourly updated zonal operating reserve demand curves(Z-ORDCs) is proposed in this paper. Reserve zones are defined by the approach of spectral clustering. A case study on system performances using the RTS-73 test system is given. Comparisons are made between the choices of reserve policies(e.g., single, seasonal or dynamic zones) and of reserve zone partitioning methods.

232 **Effects of Uncertainties in Frequency Regulations on Probabilistic Power Flow Analysis**

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Uncertainties in frequency regulations (FR) of generators and loads, and their effects on

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probabilistic power flow (PPF) analysis are addressed in this paper. The conventional PPF analysis is based on power flow model, without considering the frequency regulation. However, according to frequency regulation characteristics, generation outputs and load demand will respond to frequency deviation. Furthermore, since owners of generator units have strong economic motivations to prevent effective governing response as expected, and the load-frequency regulation coefficient of load varies with its components, the overall regulation coefficients of system cannot be completely determined and thus have some uncertainties. With some assumptions on the probabilistic distributions of regulation coefficients of generators and loads, a probabilistic power flow problem considering uncertainties in frequency regulation is presented and then solved by point estimate method (PEM). Simulations results from the IEEE-9 bus system and a 173-bus in real life with and without uncertainties in frequency regulation coefficients considered are presented and compared.

233 **Impacts of Transient Instability on Power System Reliability**

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This paper addresses the effects of transient instability on power system reliability. Composite system reliability evaluation has been performed based on steady-state estimation of load curtailments. In composite reliability evaluation, after each contingency, faulted components are assumed to be isolated from the rest of the system immediately and the system is assumed to return to a stable state with proper generation rescheduling for minimum load curtailments. In this context, minimum load curtailments are usually performed by solving linear/non-linear programming optimization problems. Although the optimization problem with minimum load curtailment may find a steady-state feasible solution, a stable transition to a post-fault stable equilibrium point is not guaranteed. In this paper, three probabilistic transient stability indices are proposed to assess system robustness against transient contingencies and update the reliability indices. Transient stability direct methods are used in assessing system stability and determining the probabilistic stability indices. This method is applied on the reduced WECC(Western Electricity Coordinating Council) system and the results showed that the effect of transient instability should not be ignored.

235 **Probabilistic Evaluation of Long-term Stability Considering Secondary Contingency Scenarios**

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This paper studies the effects of secondary contingency (N-1-1) on stability of power system in long time duration transient state considering state probability. The Vietnam power system which includes all level voltages up to 500 kV is utilized. The only 500 kV level system is analyzed by N-1-1 contingency criterion to define vulnerabilities of power grid. The dynamic simulation is implemented in vulnerability-based power system scenarios to verify long-term

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stability. The dynamic models of generators, governor, excitation system, maximum excitation limiters, static VAR compensators and load tap changers are built up based on real data of Vietnam power system.

237 **Application of Voltage Sensitivity Analysis in a Probabilistic Context for Characterizing Low Voltage Network Operation**

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The massively dispersed nature of power distribution networks and their current unobservability will drive distribution utilities to hierarchize the integration of automation in their systems. Given the complete lack of real-time information in Low Voltage (LV) networks, state estimation techniques specifically tailored for these systems will not come for the foreseeable future. Considering delayed Smart Meter (SM)recordings as the only current source of information in LV networks, this paper presents a probabilistic method that uses sensitivity analysis and quarter-hourly SM measurements for characterizing and setting boundary values for LV network operation indices. Such information can be useful in the preprocessing phase of state estimation techniques focusing on the Medium Voltage (MV) or on the LV (in a later phase) level. The proposed method is applied for analyzing a real LV feeder and its outputs are compared to the ones of a deterministic direct sensitivity analysis method, whose accuracy has been previously demonstrated, as well as to the ones of a probabilistic Monte Carlo (MC) simulation.

238 **Capacity Value of Solar Power**
Report of the IEEE PES Task Force on Capacity Value of Solar Power

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This paper reviews methods used for adequacy risk assessment considering solar power, and for assessment of the capacity value of solar power. The properties of solar power are described as seen from the perspective of the balancing authority, comparing differences in energy availability and capacity factors with those of wind. Methodology for risk calculations considering variable generation (VG) are then surveyed, including the probability background, statistical estimation approaches, and capacity value metrics. Issues in incorporating VG in capacity markets are described, followed by a review of applied studies considering solar

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power. Finally, recommendations for further research will be presented.

239 **Reactive Power Adequacy Assessment of Composite Power System Based on Interior Point Method and Genetic Algorithm**

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The solution of optimal load curtailment for the selected system contingency states is the most important step for the reliability analysis of composite power system. The linear reactive remedial model considering the bus voltage and reactive power constrains was formulated first based on the decouple AC load flow model. Aiming at dealing with the discrete control variables in the reactive power optimal problem, a hybrid optimal method combined with interior point method and Genetic Algorithm (GA) method is proposed. Some reliability indices are defined to represent the reactive power adequacy similar to the indices used for representing active power adequacy in this paper. Case studies have been carried out on the modified IEEE RTS to validate the proposed optimal algorithm and investigate the effect of discreteness of shunt compensation capacity and bus voltage on system reliability indices.

240 **Impact of High Wind Penetration on Variability of Unserved Energy in Power System Adequacy**

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This paper presents results on variability of out-turn shortfalls about the expected value indices which are usually presented in resource adequacy studies, for a range of Loss of Load Expectation (LOLE) levels and installed wind capacities in a test system generally representative of future Great Britain system scenarios. While the details of results will clearly vary between systems, one very general conclusion is possible. In the results presented, for a given LOLE level, the probability of very severe out-turn in a future peak season is much greater at high installed wind capacity. Thus for this system, as the installed wind capacity increases, a constant level of LOLE cannot be taken as an indicator of an unchanging overall risk profile of the system. This further demonstrates that in any system, LOLE cannot be assumed to be a good summary statistic of risk profile as the installed variable generation (VG) capacity increases, and that it might be necessary to reconsider the near-universal use of expected value risk indices as the main headline indices in utility adequacy studies.

241 **Effects of Risk Aversion on Market Outcomes: A Stochastic Two-Stage Equilibrium Model**

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Paper ID	Title, Author(s), Affiliation, Abstract

This paper evaluates how different risk preferences of electricity producers alter the market-clearing outcomes. Toward this goal, we propose a stochastic equilibrium model for electricity markets with two settlements, i.e., day-ahead and balancing, in which a number of conventional and stochastic renewable (e.g., wind power) producers compete. We assume that all producers are price-taking and can be risk-averse, while loads are inelastic to price. Renewable power production is the only source of uncertainty considered. The risk of profit variability of each producer is incorporated into the model using the conditional value-at-risk (CVaR) metric. The proposed equilibrium model consists of several risk-constrained profit maximization problems (one per producer), several curtailment cost minimization problems (one per load), and power balance constraints. Each optimization problem is then replaced by its optimality conditions, resulting in a mixed complementarity problem. Numerical results from a case study based on the IEEE one-area reliability test system are derived and discussed.

242 **Relation formulation between daily and hourly load curve based Loss of Load Expectation Indices**

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This paper develops a conversion function and method transforming from daily peak load curve used LOLED [days/year] to hourly load curve used LOLEH[hours/year] firstly. The indices can not only be conversed just arithmetically but also have different characteristics physically because of using their different load curves. The conversion function is formulated as variables of capacity and forced outage rate of generator, hourly load daily load factor and daily peak load yearly load factor, etc. Therefore, the conversion function ($\gamma = \varphi(\cdot)$) cannot be formulated in simple but in complex and difficult. In this study, therefore, the function is formulated as linear times of separated two functions. One is exponential formed conversion function of daily load factor. Another is formulated exponential typed conversion function of daily peak load yearly load factor. Furthermore, this paper presents algorithm and flow chart for conversing from LOLED [days/year] to LOLEH[hours/year]. The proposed conversion function is applied to sample system and actual KPS(Korea Power System) in 2015. The exponent coefficients of the conversion functions are assessed using proposed method. Finally, assessment errors using conversion function for case studies of sample system and actual system are evaluated to certify the firstly proposed method.

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243 **Optimal Feeder Reconfiguration and Distributed Generation Placement for Reliability Improvement**

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This paper presents a methodology to determine the optimal distribution system feeder reconfiguration and distributed generation placement simultaneously, and is optimal in that the system reliability is maximized. An important consideration in optimal distribution system feeder reconfiguration is the effect of the variable output of intermittent resources. The work presented in this paper considers the stochastic behavior of variable resources, and open/close status of the sectionalizing and tie-switches as variables in determining the optimal DG locations and optimal configuration that enhance system reliability. Genetic algorithm is applied to search for the optimal or near-optimal solution. The proposed method is demonstrated on a 33-bus radial distribution system, which is extensively used as an example in solving the distribution system reconfiguration problem.

244 **Multi-objective Optimal Control Research For WTGS**

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Due to the uncertainty of wind speed and the complex operation environment for wind turbine, the wind turbine generator system (WTGS) is relatively difficult to control, it will inevitably bring power quality problems to power system. In order to guarantee power quality and the WTGS operation conditions, the optimal control of wind turbines is needed. This paper employs ε-SVR algorithm to model system output power, transmission chain vibration and wind speed, with maximizing the system output power, minimizing change rate of system output power and minimizing transmission chain vibration as the control objectives, uses the improved SPEAII algorithm to resolve multi-objective optimal control model, finally using the cluster analysis and based on wind turbine operation conditions, selects the compromise solution, gets the generator torque reference setting and the pitch angle setting. The simulation results show that the proposed method has high efficiency of decision-making, realizes the control objectives, and abates the fatigue load of wind turbine.

245 **Risk-Based Penalty Price Determination Procedure for Transmission Constraint Relaxations**

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The electric power system is one of the most complex engineered systems. It is, thus, a challenge to design a market that is efficient, transparent, and provides the proper incentives

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to market participants. Existing market models employ constraint relaxations, which enable various constraints to be relaxed (violated) for a high penalty price. This paper examines the practice of allowing transmission assets to be overloaded in market models. While most overloads are corrected by dispatch operators before the actual operational state, some overloads are realized. Existing constraint relaxation practices specify the same penalty price regardless as to the line's voltage, anticipated current flow, probability of a contingency, or overall impact on operational security. This paper proposes a straightforward way to modify existing practices to assign higher penalty prices to lines that receive a higher risk index. The approach is tested on a real-world, large-scale system, the PJM Interconnection.

246 **Reliability Evaluation of Power Systems Incorporating Maintenance Policy with Partial Information**

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This paper proposes a partially observable semi-Markov decision process (POSMDP) based preventive maintenance model for power system reliability assessment. In this paper, we utilize a model that considers the components can fail due to both random and aging failure. Based on this model, optimal maintenance and inspection policy are performed to prevent aging failure. Moreover, to account for condition monitoring uncertainties, the inspection result gives a probabilistic assessment of component's conditions. The proposed method is applied to a modified IEEE RTS-79. Comparing with the traditional power system reliability assessment model, this one enables a more realistic power system.

247 **Provision of rotating reserves from wind power in a hydro-dominated power system**

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This paper investigates how wind power can contribute to the provision of rotating reserves in a hydro-dominated power system with limited transmission capacity to an exogenous power market. We emphasize on the impacts different schemes for providing rotating reserves has on the generation dispatch and rotating reserve (RR) cost. Due to the flexibility provided by hydropower, the system is well suited for facilitating a large share of intermittent energy.

We approached this by building a model based on Stochastic Dual Dynamic Programming (SDDP), which efficiently handles multistage stochastic problems.

A case study is presented based on the properties from the Nordic power system. Results shows that for wind penetration levels above 20%, some wind power is used for the provision of upwards RR at higher costs than the hydropower could provide, but freeing up more flexibility for the hydropower units and subsequently higher overall gain. The use of wind power to provide downwards RR proved to be very cost efficient, as there is no opportunity cost associated with the use of wind power.

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249 **Analysing Correlated Events in Power System Using Fault Statistics**

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Power system automation requires logical presumptions made on practical grids to correctly comprehend and manage complex and correlated faults occurring in real world systems. Traditional grid fault analysis methods lack in-depth understanding of these complex events and demand development of approaches that make use of available data to address this problem. Here, the traditional classification approach and challenges relating control equipment in power system are reviewed and a method observing the affected customers during faults along with grid design is discussed based on Swedish case study data. Various contrasting observations are made on the data recorded over two time periods to understand the trend developing over years. Moreover, it will be shown that the classification method also has potential in identifying weak spots in the grid when it comes to the reliability of control equipment.

250 **A Dynamic Programming-Based Heuristic Approach for Optimal Transmission Switching Problem With N-1 Reliability Criterion**

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Minimization of operating costs is one of the most important objectives of power system operators. To achieve this goal, several optimization problems such as unit commitment and optimal power flow have been introduced. Historically, in these problems, the transmission network has been considered as a static system, i.e., the ability of transmission lines switching is not modeled. On the other hand, it has been shown that transmission line switching can significantly reduce operating costs by the means of topology modification. However, considering this capability, a large number of binary variables are introduced in the objective function, and as a consequence, the computation time will be considerably increased. To address this problem, this paper tries to propose an effective method based on the dynamic programming algorithm for solving the optimal transmission switching (OTS). In this method, firstly the OTS is modeled as a step by step problem. Then, in order to reduce the computation time, in each step, some lines are chosen as candidates for outage by using appropriate criteria. The proposed method not only reduces the computation time but also considers the effects of transmission switching on the operational constraints that have not been modeled in the previous DC models. It is also shown that the method can effectively consider the N-1 security criterion. Finally, in order to illustrate the effectiveness of the proposed method, it is applied to the IEEE 118-Bus test system and the results are discussed.

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251 **A Unified Analysis of the Impacts of Stochasticity and Low Inertia of Wind Generation**

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This paper proposes a new method to model wind generation in power system reliability evaluation that not only considers the uncertainty of wind speed and mechanical failures of wind turbines but also includes the impacts of wind's low inertia property. Due to the stochasticity and low inertia of wind generation, power system stability and reliability are significantly affected. When wind generators are integrated into the grid, a strategy to ensure the system stability is that wind generators are required to operate at a lower level than their maximum available output power. The effect of this requirement is that not all of the available wind power will be used in the system, which in turn affects the contribution of wind generation in power system availability. The proposed model is implemented using Monte Carlo methods. For every system state, the maximum integrated amount of wind power is determined based on frequency regulation requirements. Then, this amount of power is used along with the stochastic model of wind speed in the reliability modeling. The proposed method is demonstrated on the IEEE RTS system. Power system reliability with and without considering the impacts of wind stochasticity and low inertia are compared to show the effectiveness of the proposed method.

252 **Bulk Power System Reliability Evaluation Considering Optimal Transmission Switching and Dynamic Line Thermal Rating**

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Power system operators are faced with the increasingly complicated operating condition of bulk power systems. Due to the huge investment needed to build new power delivery facilities, cost-effective solutions such as new operational strategies are becoming more attractive in the recent years. Optimal transmission switching (OTS) and dynamic thermal rating (DTR) are such cost-effective technologies which offer a potential solution to improving the power system reliability by more fully utilizing the existing power delivery assets. In this paper, these two technologies are discussed, which are then incorporated into the reliability evaluation procedure for the power system. Case studies are conducted on a modified RTS-79 system using MATLAB and CPLEX. The obtained simulation results show that with the enforcement of either OTS or DTR, the overall system reliability can be improved, and system reliability can be further improved if both technologies are enforced.

Paper ID	Title, Author(s), Affiliation, Abstract

253 **Wind Farm Dynamic Analysis in terms of Turkish Grid Codes**

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Wind power plant installations continue to increase worldwide because it is a kind of renewable and harmful emissions-free energy source. The increased capacity of wind power needs the new strict requirements related to the grid connections of wind generators. The requirements defined in the grid codes can be states as reactive power control, fault ride-through (FRT) capability of the wind turbines, active power and frequency control. The grid codes affect inevitably the developments of wind turbine technology. Today wind power plants are expected to support the grid and provide ancillary services much like conventional power plants. This paper presents a simulation based monitoring approach for the dynamic behavior of a wind farm with doubly fed induction generators (DFIG).Simulations are performed to check how Turkish grid codes complies with the dynamic effects of the wind turbines on the power grid as a reflection of disturbances. The response of wind turbines at the point of common coupling (PCC) are analyzed. Simulation studies are conducted using the power system simulation tool DIgSILENT Power Factory. From this analyses, it can be concluded that Turkish grid codes need to be detailed and expanded to maximize the capacity of wind power plants keeping stability constant in Turkish power system.

254 **Identification of Critical Line-Generation Combinations for Hypothesized Joint Line-Generation Attacks**

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The increasing load demand is pushing power system to operate near its limit, making it more vulnerable to various disturbances and attacks, especially those that might initiate cascading failures. In this study, the joint line-generation attack is introduced which assumes that the lines and generators can be tripped by malicious attacks simultaneously, and it is a natural extension of the previous node-only or line-only attacks. The joint line-generation attack strategy is explored based on a search space reduction algorithm. The simulation is conducted based on several representative test systems. The performance of the proposed attack strategy is compared with other attack strategies and the computational burden is analyzed. It is demonstrated that the proposed attack strategy is effective and computationally efficient. This work can provide some meaningful insight on how to prevent power system cascading failures initiated by joint attacks.

Paper ID	Title, Author(s), Affiliation, Abstract

255 **A Resilient Power System Operation Strategy Considering Presumed Attacks**

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Power system operation is facing increasing cyber and physical attack risks and it is pressing to develop effective methods to improve the resiliency of electric power infrastructure against malicious attacks. In this study, a holistic resiliency framework is proposed by extending the conventional security-constrained optimal power flow analysis (SCOPF) to incorporate the presumed risk caused by the attacks. The improved solution method is studied by combining particle swarm optimization, primal-dual interior point (PDIP)method and parallel computing. The case studies conducted on IEEE 39-bus and 118-bus systems demonstrate the proposed SCOPF model is able to improve the resiliency of power system for the presumed attacks. This study can provide some meaningful insights on improving the power system operation resiliency.

256 **Using VaR and CVaR Techniques to calculate the Long-term Operational Reserve**

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Generally, the more Renewable Energy Sources (RES) in generation mix the more complex is the problem of reliability assessment of generating systems, mainly because of the variability and uncertainty of generating capacity. These short-term concerns have been seen as a way of controlling the amount of spinning reserve, providing operators with information on operation system risks. For the medium and long-term assessment, such short-term concerns should be accounted for the system performance [1,2], assuring that investment options will result in more robust and flexible generating configurations that are consequently more secure. In order to deal with the spinning reserve needs, this work proposes the use of a risk based technique, Value-at-Risk and Conditional Value-at-Risk, to assist the planners of the Electric Power Systems (EPS) as regards the design of the flexibility of generating systems. This methodology was applied in the IEEE-RTS-96 HW producing adequate results.

257 **Impact Evaluation of the Network Geometric Model on Power Quality Indices using Probabilistic Techniques**

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Distribution Power System performance assessment is usually based on continuity indicators

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and power quality measurements. Generally, these evaluations are performed using distinct mechanisms, where continuity is assessed by past network performance observations and/or predicted simulation, whereas power quality is evaluated using electronic measurements. In fact, the concepts of reliability and power quality are dissociated, mainly when distribution power system performance is assessed. However, the current diversity of loads and sources, with more sensitivity to voltage variations, requires a wider ranging of power system tools, which consider aspects of both continuity and power quality effects. Aiming for a distribution systems performance approach that considers both reliability and power quality issues into a unique evaluation framework, aspects related to the systems voltage as well as distorting phenomena affecting the voltage waveform need to be modeled. This paper proposes the impact assessment of network geometric model on power quality indices using simulation techniques. The main idea is to include a short-circuit model into a sequential Monte Carlo algorithm in order to assess power quality indices through estimates. The proposed methodology is applied to the IEEE test feeder with 34 nodes.

258 **Prediction of Availability and Charging Rate at Charging Stations for Electric Vehicles**

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To enable better smart charging solutions, this paper investigates the day-ahead probabilistic forecasting of the availability and the charging rate at charging stations for plug-in electric vehicles. Generalized linear models with logistic link functions are at the core of both forecast scenarios. Moreover, the availability forecast at a charging point is simply a binomial problem, whereas the charging rate forecast is handled via an ordered logistic model after categorizing the feasible range of values. These two scenarios are evaluated on real data collected from two representatives of the most occupied charging points in the Netherlands, with the focus of the analysis kept at the selection of essential regressors. Based on the ranked probability scores associated with the day-ahead forecasts generated for the last nine months of 2015, it is concluded that the usefulness of predictive models depends highly on the charging station. When contributing substantially to performance, such models possess a simple structure with a few basic lagged and indicator variables.

260 **Probabilistic Assessment of PMU Integrity for Planning of Periodic Maintenance and Testing**

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The standard C37.118.1a-2014 has specified the permissible limits for PMU measurement errors under various static and dynamic test conditions. This paper proposes a statistical measure to evaluate the probability of PMU performance degradation with regards to certain

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standard requirements. The proposed approach is implemented using a field calibrator system for phasor measurement units (PMUs). Assessment of the test results provides an additional insight about: (a) whether the expected functionality and integrity of the PMUs is maintained over time; (b) which synchrophasor standard requirements are most vulnerable for a given device over time; (c) when the maintenance schedule needs to be expedited on certain PMUs based on observed performance degradation probabilities; and (d) the risks of loss of trustworthiness of various end-use synchrophasor-based applications. The applicability of the suggested technique is verified through implementation on several PMUs in a calibration and testing set-up.

261 **Urban Distribution Grid Line Outage Identification**

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The growing integration of distributed energy resources (DERs) in urban distribution grids raises various reliability issues due to complex uncertainties. With the large-scale penetration of DERs, traditional outage detection methods, which rely on customers making phone calls and smart meters' "last gasp" signals, will have limited performance because 1) the renewable generators can supply powers after line outages, and 2) many urban grids are mesh and line outages do not affect power supply. To address these drawbacks, we propose a new data-driven outage monitoring approach based on the stochastic time series analysis with the newly available smart meter data utilized. Specifically, based on the power flow analysis, we prove that the statistical dependency of time-series voltage measurements has significant changes after line outages. Hence, we use the optimal change point detection theory to detect and localize line outages. As the existing change point detection methods require the post-outage voltage distribution, which is unknown in power systems, we propose a maximum likelihood method to learn the distribution parameters from the historical data. The proposed outage detection using estimated parameters also achieves the optimal performance. Simulation results show highly accurate outage identification in IEEE standard distribution test systems with and without DERs using real smart meter data.

262 **Probabilistic Modeling of Nodal Electric Vehicle Load due to Fast Charging Stations**

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In order to reduce greenhouse gas emission and fossil fuel dependence, Electric Vehicle (EV) has drawn increasing attention due to its zero emission and high efficiency. However, new problems such as range anxiety, long charging duration and high charging power may threaten the safe and efficient operation of both traffic and power systems. This paper proposes aprobabilistic approach to model the nodal EVload at fast charging stations in integrated power and transport systems. Following the introduction of the spatial-temporal model of moving EV loads, we extended the model by taking fast charging station into consideration. Fuzzy logic

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inference system is applied to simulate the charging decision of EV drivers at fast charging station. Due to increasing EV loads in power system, the potential traffic congestion in fast charging stations is modeled and evaluated by queuing theory with spatial-temporal varying arrival and service rates. The time-varying nodal EV loads are obtained by the number of operating fast chargers at each node of the power system. System studies demonstrate that the combination of AC normal and DC charging may share the EV charging demand and alleviate the impact to power system due to fast charging with high power.

263 **Reliability Evaluation in Power Distribution System Planning Studies**

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In distribution system planning studies, reliability evaluation is performed during optimization procedure to calculate the interruption cost, DISCO's income and to check the viability of constraints related to reliability indices. In each iteration of the optimization algorithm a special plan is evaluated that is different from other plans. So the configuration and specification of the network which is one of the input information for reliability evaluation is changing continuously that makes difficulties for this evaluation. To solve these difficulties, this paper presents a systematic method for reliability evaluation in distribution planning studies. The proposed approach can be implemented as a subprogram in comprehensive software of distribution system planning and design.

265 **Developing a Multi-Objective Framework for Planning Studies of Modern Distribution Networks**

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This paper presents a new framework for planning studies of modern distribution networks. Presence of electric vehicles (EVs) and various technologies of distributed generation (DG) technologies are considered in the studies as two upcoming events of the future systems. In this regard, place and capacity of DG units along with the reinforcement of distribution lines are determined running a multi-objective (MO) optimization algorithm. Total losses of the distribution network along with annualized cost of expansion plans including investment, operation and maintenance costs are introduced as the main criteria which should be optimized in the proposed framework. An effective Posteriori optimization tool, i. e. Non-Dominated Sorting Genetic Algorithm II (NSGAII) is borrowed to solve the attained optimization problem of the studies. The proposed planning procedure is implemented on a distribution test system (IEEE RBTS-BUS5) and the optimal solutions have been found which shows the applicability and effectiveness of proposed algorithm.

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266 **An Analytical Framework for Operational Reliability Studies of Highly Wind Integrated Power Systems**

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This paper presents a new framework for evaluating contribution of wind farms in operational reliability level of power systems. In this regard, at first, it provides a short-term analytical model well designed to represent intermittent and uncertain nature of wind power. Combining the attained multi-state model of wind farms with the other committed generating units, operational risk of the system is evaluated. The concept of Pennsylvania-New Jersey-Maryland (PJM), previously developed to assess the short-term/mid-term reliability of conventional generating units, is revisited in this paper to more practically incorporate wind farms in reliability studies of the power system. The proposed algorithm is implemented on the IEEE-RTS to investigate its effectiveness.

267 **Prediction of current in a substation in order to schedule thermography**

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It is important to predict the current in a line in the electrical grid for example when planning thermography or handling dynamic rating. This paper takes data from a Swedish substation from 10 years and applies analysis of variance(ANOVA) to construct a linear model. The factors are the time of the day, the day of the week and the week number. About two thirds of the variance in the data can be explained by the model, but the means are too low to attain a current of at least one third of the current for which the equipment is rated. Thus the model is not good enough to plan thermography for the studied bay in the substation. However the model is able to predict the current and can also be used to predict power flows in the electric network.

269 **Introducing Distributed Learning Approaches in Wind Power Forecasting**

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Renewable energy forecasting is now of core interest to both academics, who continuously propose new forecast methodologies, and forecast users for optimal operations and participation in electricity markets. In view of the increasing amount of data being collected at power generation sites, thanks to substantial deployment of generating capacities and increased temporal resolution, it may now be possible to build large models accounting for all space-time dependencies. This will eventually allow to significantly improve the quality of short-term renewable power forecasts. However, in practice, it is often the case that operators of these generation sites do not want to share their data due to competitive interests.

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Consequently, approaches to privacy-preserving distributed learning are proposed and investigated here. These permit to take advantage of all potential data collected by others, without having to ever share any data, by decomposing the original large learning problem into a number of small learning problems that can be solved in a decentralized manner. As an example, emphasis is placed on Lasso-type estimation of autoregressive models with offsite observations. Different applications on medium to large datasets in Australia (22 wind farms) and France (85 wind farms) are used to illustrate the interest and performance of our proposal.

277 **A Two-stage Wind Speed Model for Multiple Wind Farms Considering Autocorrelations and Cross-correlations**

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Collected wind speed time series (WSTS) has three major characteristics: randomness, autocorrelation and cross-correlation, which have significant effects on the wind speed modeling for power systems containing wind energies. Most WSTS models only consider some of the above characteristics, which may significantly reduce the computation accuracy on the analysis of wind-integrated power systems. This paper presents a two-stage model for WSTS at multiple wind sites. This model considers the wind speed autocorrelation for each WSTS in the first stage, and wind speed cross-correlation for all WSTSs in the second stage. The inverse transformation is used to derive the analytical correlation relationship between multiple WSTSs and multiple time series of normal distribution (TSND). Then modeling multiple WSTSs with given correlations can be done by building multiple TSNDs that meet appropriate autocorrelations and cross-correlations using an autoregressive model. Case studies demonstrate that the proposed model is capable of simulating WSTS with higher accuracy than the improved correlation method, the time-shifting technique, and the Copula method.

278 **A stochastic Optimal Model of Micro Energy Internet Contains Rooftop PV and CCHP System**

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Micro Energy internet generally refers to energy system with multi-energy synergism, is achieved through energy conversion, storage, demand response and other technologies, realizes coupling energy and information deeply. This paper introduces a stochastic optimal operation model of micro Energy Internet contains CCHP system and rooftop PV modules. A representative scenarios method is used to describe the uncertainty of PV output power. A stochastic MILP model with probability was established and verified by actual data in the case study section.

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