AUSTRALIA-CHINA WORKSHOP:

# MEASUREMENT CHALLENGES FOR ELECTRICAL ENERGY SECURITY

5-8 SEPTEMBER 2017

## PROGRAM

中国计量科学研究院
National Institute of Metrology,China

Australian Academy of Science

Australian Government
Department of Industry, Innovation and Science

National Measurement Institute

AUSTRALIA-CHINA WORKSHOP:

# MEASUREMENT CHALLENGES FOR ELECTRICAL ENERGY SECURITY

5-8 SEPTEMBER 2017

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# DIRECTORS' WELCOME

Greetings from the Directors of NMIA and NIM!

As the directors of the National Measurement Institute of Australia (NMIA) and China's National Institute of Metrology (NIM) it gives us great pleasure to welcome delegates and guests to the *Australia-China workshop: Measurement challenges for electrical energy security*.

NMIA and NIM develop and maintain a wide range of measurement capabilities and solutions that improve industry productivity, optimise products and processes, and help solve real-world problems. Both organisations recognise that a secure electricity supply, that is, one that is reliable, high-quality, efficient and sustainable, is essential for the prosperity of their nations, and that measurement science and technology are central to this goal. Because of this, NMIA and NIM have had close linkages for many years in developing measurement standards and systems in support of their national electricity transmission and distribution industries.

NMIA and NIM are very pleased to be able to continue their long-standing cooperation by hosting this workshop, with the invaluable support of the Australia-China Science and Research Fund (ACSRF) and the Australian Academy of Science.

Through the workshop, Australian and Chinese stakeholders in the university, research agency, government, electricity supply, and manufacturing sectors can identify and discuss the measurement challenges of electrical energy security and strengthen the cooperative research links needed to respond.

As scientists and metrologists, we are passionate about the importance of good measurement. By sharing and leveraging each other's expertise, we are confident that both of our countries will make great strides forward. We encourage all workshop participants to share in this passion and make the most of the event as we lay the groundwork for a roadmap of measurement capability that will secure the supply of electricity in Australia and China for the $21^{st}$ century.


## DR PETER FISK

**CEO and Chief Metrologist**
**National Measurement Institute of Australia (NMIA)**



## MR FANG XIANG

**Director**
**National Institute of Metrology (NIM) China**

# PROGRAM OF EVENTS

## DAY 1: TUESDAY, 5 SEPTEMBER SHINE DOME, 15 GORDON STREET, ACTON

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|---|---|
| **8.00** | **Registration** |

### PLENARY SESSION 1

**Chair: Dr Ilya Budovsky, National Measurement Institute of Australia (NMIA)**

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|---|---|
| **8.30** | **Introduction and housekeeping**<br>**Dr Ilya Budovsky**<br>National Measurement Institute of Australia (NMIA) |
| **8.40** | **Welcome and opening**<br>**Dr Alan Finkel** AO FAA FTSE<br>Australia's Chief Scientist |
| **8.50** | **Welcome from National Measurement Institute of Australia (NMIA)**<br>**Dr Peter Fisk**<br>CEO and Chief Metrologist<br>National Measurement Institute of Australia (NMIA) |
| **9.00** | **Government strategies and programs in support of scientific collaboration between Australia and China**<br>**Ms Sarah Brown**<br>Australian Government Department of Industry, Innovation and Science |
| **9.20** | **Smart grids and the challenges of metrology**<br>**Mr Qing Fang**<br>Deputy Director<br>National Institute of Metrology (NIM) China |
| **9.50** | **Group photo and morning tea** |

### PLENARY SESSION 2

**Chair: Dr Angela Samuel, National Measurement Institute of Australia (NMIA)**

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|---|---|
| **10.30** | **Addressing challenges for the future grids—harmonics standardisation**<br>**Professor Firuz Zare**<br>University of Queensland, Australia |
| **11.00** | **On-site measurements of frequency application for POD (power oscillation damper), South Pine, Greenbank and Blackwall SVC example**<br>**Dr Rizah Memisevic**<br>Powerlink, Australia |
| **11.30** | **Transient voltage and current measurement and stability and security analysis for power transmission and distribution system**<br>**Dr Yinan Geng**<br>Tsinghua University, China |
| **12.00** | **Lunch** |

## PLENARY SESSION 3

**Chair: Dr Qing He, National Institute of Metrology (NIM) China**

| | |
|---|---|
| **13.00** | **Experience with high voltage and smart grid related European metrology projects**<br>**Dr Jari Hällström**<br>VTT Technical Research Centre of Finland Ltd |
| **13.30** | **Smart grid and beyond—towards a socio-cyber-energy future**<br>**Professor Xinghuo Yu**<br>RMIT University, Australia |
| **14.00** | **Measurements underpinning electrical energy security in Australia and planning for the workshop**<br>**Dr Ilya Budovsky**<br>National Measurement Institute of Australia (NMIA) |
| **14.30** | **Move to breakout sessions** |
| **14.45** | **Breakout sessions commence**<br>**Group 1: Power quality (see page 16)**<br>**Group 2: Measurement of power quantities in electrical grids (see page 24)** |
| **15.15** | **Afternoon tea** |
| **15.45** | **Breakout sessions continue** |
| **17.15** | **Welcome barbeque** |

## DAY 2: WEDNESDAY, 6 SEPTEMBER

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|---|---|
| **8.00** | **Bus from Canberra to Sydney**<br>**Departure point: Shine Dome, 15 Gordon Street** |
| **12.30** | **Arrival at National Measurement Institute of Australia (NMIA)** |
| **13.00** | **Lunch** |
| **14.00** | **Introduction and welcome to National Measurement Institute of Australia (NMIA)**<br>**Dr Lindsey Mackay**<br>General Manager<br>National Measurement Institute of Australia (NMIA) |
| **14.30** | **Tour of NMIA's Lindfield Laboratories** |
| **17.00** | **Bus to Mantra Chatswood** |

## DAY 3: THURSDAY, 7 SEPTEMBER NMIA, 36 BRADFIELD ROAD, LINDFIELD

| | |
|---|---|
| 8.15 | Bus from Mantra Chatswood to National Measurement Institute of Australia (NMIA) |
| 9.00 | Breakout sessions continue |
| | Group 1: Power quality (see page 16) |
| | Group 2: Measurement of power quantities in electrical grids (see page 24) |
| | Group 3: Storage (see page 31) |
| | Group 4: Data security (see page 35) |
| 10.30 | Morning tea |
| 11.00 | Breakout sessions continue |
| 11.30 | Breakout sessions: Discussion and formulation of collaboration proposals |
| 12.00 | Lunch |
| 13.00 | Breakout sessions: Discussion and formulation of collaboration proposals (continued) |
| 16.30 | Bus from National Measurement Institute of Australia (NMIA) to Mantra Chatswood |
| 18.00 | Bus from Mantra Chatswood to King Street Wharf |
| 19.00 | Official workshop dinner and Sydney Harbour cruise |
| 22.00 | Bus from King Street Wharf to Mantra Chatswood |

## DAY 4: FRIDAY, 8 SEPTEMBER NMIA, 36 BRADFIELD ROAD, LINDFIELD

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|---|---|
| 8.15 | Bus from Mantra Chatswood to National Measurement Institute of Australia (NMIA) |
| 9.00 | Presentations from breakout groups<br>Finalise collaboration proposals |
| 12.00 | Lunch |
| 13.30 | End of workshop |
| 14.00 | Bus from National Measurement Institute of Australia (NMIA) to Sydney airport |

# ABOUT THE WORKSHOP

The electrical energy industries in Australia and China rely on measurement science and technology to solve current and emerging challenges. These needs are only expected to increase in the future.

This workshop will explore these challenges, showcase present scientific achievements, and formulate a roadmap of future requirements for measurement research in electrical energy security. It is anticipated that the roadmap will inform future research project opportunities to address industry needs.

The workshop is fully funded by the government of Australia (via the Australia–China Science and Research Fund (ACSRF).

# WORKSHOP OBJECTIVES

The workshop aims to:

- share measurement strategies on electrical energy security;
- lay the foundation for a roadmap of measurement capabilities that will enable the security of electricity supply for the 21st century;
- facilitate cross-sector discussions between senior leaders in universities, research institutions, government research agencies and electricity supply utilities and manufacturers;
- allow representatives from Australia and China to share experiences and insights;
- initiate new and strengthen existing collaborations; and
- develop a foundation for future collaboration, including opportunities for funding.

# WORKSHOP CHAIRS


## DR ILYA BUDOVSKY

**National Measurement Institute of Australia (NMIA)**
ilya.budovsky@measurement.gov.au


Dr Ilya Budovsky heads the Electricity Section at the National Measurement Institute of Australia (NMIA). He is responsible for the development and dissemination of Australian physical standards of measurement for electricity, time and frequency. He also leads the Energy Sector Focus Team that aims at engaging with the Australian energy sector and raising the impact of measurements in the sector. Dr Budovsky is a Fellow of Engineers Australia, Senior Member of IEEE, the Australian representative to the Consultative Committee for Electricity and Magnetism and Chair of NATA's Accreditation Advisory Committee on Calibration.


## DR QING HE

**National Institute of Metrology (NIM) China**
heqing@nim.ac.cn


Qing He is the director of Electricity and Magnetism Division, NIM. He joined NIM in 1988. From then to 2003, he worked on establishing the Chinese QHR standard based on a cryogenic current comparator. At the same time, he helped industry to solve some precise measurement problems, such as low magnetic flux and permeability of soft magnetic material. He developed a method to measure mutual inductance by using a digital integrator, which became the technical basis of the Chinese Joule Balance. His current research interests are to evaluate the uncertainty of smart meters on site by means of big data, the metrological service for smart grid, and the electrical vehicle charger.

# PLENARY CHAIR


## DR ANGELA SAMUEL

**Director, International Relations National Measurement Institute of Australia (NMIA)**
angela.samuel@measurement.gov.au


Angela Samuel is Director, International Relations at the National Measurement Institute of Australia (NMIA). She manages NMIA's international engagements, ranging from its participation in the peak global and regional multilateral measurement forums to its bilateral relationships, including with the National Institute of Metrology (NIM) China. Over the period 2013-14, Angela coordinated the development of NMIA's "sector strategy" to develop cross-disciplinary engagement to maximise the benefits and impact of NMIA's expertise in priority economic sectors including food safety, environment, health and energy. Angela plays a leadership role in the Asia-Pacific Metrology Programme (APMP); she was a member of the APMP Executive Committee from 2008 to 2011 and has been a founding member of APMP's Developing Economies' Committee (DEC) since its establishment in 2000. Angela has a BSc(Hons) degree from the University of Melbourne and a PhD in Astronomy and Astrophysics from the Australian National University.

# PLENARY PRESENTERS

## DR ALAN FINKEL AO FAA FTSE

### Australia's Chief Scientist

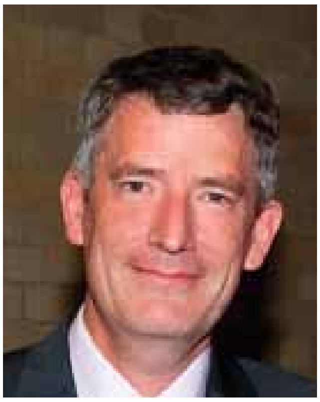
Dr Finkel commenced as Australia's Chief Scientist on 25 January 2016. He is Australia's eighth Chief Scientist. Dr Finkel has an extensive science background as an entrepreneur, engineer, neuroscientist and educator.

Prior to becoming Chief Scientist, he was the eighth Chancellor of Monash University and the eighth President of the Australian Academy of Technology and Engineering (ATSE).

Dr Finkel was awarded his PhD in electrical engineering from Monash University and worked as a postdoctoral research fellow in neuroscience at the Australian National University.

In 1983 he founded Axon Instruments, a California-based, ASX-listed company that made precision scientific instruments. After Axon was sold in 2004, Dr Finkel became a director of the acquiring company.

In 2006, he focused his career in Australia and undertook a wide range of activities including co-founding Cosmos Magazine. During his time at ATSE, he led the development and implementation of the STELR program for secondary school science.



## DR PETER FISK

### National Measurement Institute of Australia (NMIA)

Since graduating from the ANU in 1986 with a PhD in atomic physics, Dr Peter Fisk has worked as a Research Fellow at the Australian National University's Research School of Physical Sciences, spent a short period as a Visiting Scientist at the IBM Almaden Research Centre in California, and joined the CSIRO National Measurement Laboratory (NML) in 1991 to start and lead a new research project on atomic clock development. In 1993 he was appointed Head of the Time and Frequency group of NML.

When the National Measurement Institute of Australia (NMIA) was formed in 2004 Peter was appointed General Manager of its Physical Metrology Branch, with responsibility for developing, maintaining and disseminating Australia's standards of physical measurement (such as time, mass, and temperature).

In February 2012 Peter was appointed NMIA's Chief Executive and Chief Metrologist. Since then he has led a reform process aimed at strengthening NMIA's engagement with key economic sectors and ensuring an appropriate return for the government's investment in metrology. Peter has also held discipline-specific leadership positions in international Metre Treaty committees and from 2013-2016 chaired the Asia Pacific Metrology Programme, the regional body associated with the Metre Treaty. In that capacity, among other things, he oversaw the formal processes that deliver international acceptance of the measurement services of over 25 national measurement institutes in the region.

## MS SARAH BROWN

**Australian Government Department of Industry, Innovation and Science**
sarah.brown@industry.gov.au

Sarah Brown is currently the Manager of the International Strategy – Science and Innovation Section in the Department of Industry, Innovation and Science. She has responsibility for the overarching policy for international science and innovation engagement, including the Global Innovation Strategy under the National Innovation and Science Agenda. Her section also leads the bilateral engagement with the European Union and its Member States, the USA, Canada, Singapore and Korea. She previously held senior roles in the peak body Universities Australia, leading work on key policy and engagement documents and processes for the university sector. Ms Brown has also held various science and research related policy positions in the department, including developing and implementing research infrastructure policy and national research and science investment planning and prioritisation.

### *Government strategies and programs in support of scientific collaboration between Australia and China*

China is a key partner for Australia in terms of science and research collaboration. The strong science and research relationship between Australia and China has a long history. The Australian and Chinese governments jointly manage the Australia–China Science and Research Fund to support strategic science, technology and innovation collaboration of mutual benefit to Australia and China. In addition, the Australian Government is investing in science, innovation and research through a variety of funding bodies and the government's flagship innovation policy, the National Innovation and Science Agenda (NISA). The Global Innovation Strategy is the key international measure of NISA. The strategy provides an overarching framework and includes a series of initiatives to help Australians access international science, research and innovation collaboration opportunities. China is a world leader in many areas of science and innovation, and is one of the key partners for Australia under the strategy.

## MR QING FANG

**National Institute of Metrology (NIM) China**
fangq@nim.ac.cn

Qing Fang graduated from Beijing Jiaotong University in 1982 with a Bachelor's degree. In 1997, he graduated from the University of Science and Technology of China with a Master's degree in management science and engineering. He has served as Vice-President of the National Institute of Standardization, China. In 2007, he was appointed Vice-President of National Institute of Metrology (NIM) China. In 2009, he held concurrent positions as Vice-Chairman and Secretary General of China Energy Conservation Association.

### *Smart grids and the challenges of metrology*

With environmental pollution and climate change, the State Grid Corporation Company (SGCC) is vigorously developing renewable energy represented by solar and wind energy. Solar and wind energy is uncertain and variable, China's renewable energy is in the northwest and the load is very far away. These are new challenges to the power grid. SGCC has established a strong smart grid with UHV as the backbone. Since 2009, the state grid has launched 352 UHV projects with a total investment of 6 billion US dollars. In the renewable energy, wind power capacity grows up to 99.97 GW, solar power capacity grows up to 32.82 GW. SGCC has built 2,100 smart power stations, in the Beijing-

Shanghai highway, Qing-Yin highway, Shanghai-Chengdu highway, Nanjing-Shanghai highway. Eight hundred electric vehicle charging stations/ battery swap facilities and 40,000 charging spots have been constructed. The advanced metering infrastructure (AMI) system of SGCC covers 27 provinces and a total of 420 million energy meters. At present, SGCC is conducting research in digital energy measurement, UHV measurement, harmonic monitoring and measurement, energy meter reliability, energy meter metering data security and application.

## PROFESSOR FIRUZ ZARE


**University of Queensland, Australia**
f.zare@uq.edu.au


Firuz Zare received his PhD in power electronics from Queensland University of Technology, Australia in 2002. He has spent several years in industry as a team leader working on power electronics and power quality projects. Professor Zare has received several awards, including an Australian Future Fellowship, John Madsen Medal from Engineers Australia, European Innovation and Entrepreneurship Teaching Excellence award and Early Career Academic Excellence Research Award. He has published over 200 journal and conference papers in the areas of power electronics and power quality. He has secured seven ARC research funds, one Danish Research Fund and several research and consultancy projects worth over $8 million since 2007. Professor Zare is a Task Force Leader of Active Infeed Converters within Working Group One at the IEC standardisation TC77A. He is a Senior Member of IEEE, the Editor-in-Chief of International Journal of Power Electronics and an Associate Editor of IEEE Access journal.

### *Addressing challenges for the future grids—harmonics standardisation*

Due to the global demand for energy saving and reduction of greenhouse gas emissions, utilisation of renewable energy sources and efficient loads based on power electronics technology is increased in electricity networks. The negative aspects of this technology are very complex and not well known, affecting the reliability and robustness of the grids. Power quality of grids deteriorate due to high penetrations of different power electronics technologies utilised in many applications such as renewable energy systems and smart loads. Distribution network operators in many countries have experienced communication failures and high frequency resonances in low voltage distribution networks for which communication and signalling cannot be performed properly with distributed generators and/or loads. Prediction of grid impedance for low frequency range (below 2 kHz) is mainly defined by line and transformer impedances—which are normally inductive and restive. Grid impedance and power quality have not been investigated and measured for the frequency range of 2-150 kHz, and this is greatly needed. This presentation aims to address harmonic measuring issues of future grids at low and medium voltage level and within the frequency ranges of 0-2 kHz (existing regulations) and 2-150 kHz (new regulations).

## DR RIZAH MEMISEVIC


**Powerlink, Australia**
rmemisevic@powerlink.com.au


Rizah Memisevic has worked at Powerlink, in the Power Research Institute and at universities, as Lecturer and Assistant Professor at the Faculty for

Electrical Engineering at the University of Tuzla, Bosnia and Herzegovina and as Research Officer at the University of Queensland. He was always involved into research across multiple technical areas of renewable energy (solar and wind), energy applications (power generation), and energy and economic interaction. Dr Memisevic is a member of BH K CIGRE, the Australasian Association for Engineering Education, IEEE (Senior Member and the Institution of Engineers Australia. He has 27 years of experience in the energy domain with strong background and high accountability in development, research and investigations. He is involved in the research and design of renewable and alternative energy sources, has strong relations with major market players in the domain of the FACTS and wind energy established through multiple projects, and has 45 published papers and non-refereed publications.

### *On-site measurements of frequency application for POD (power oscillation damper), South Pine, Greenbank and Blackwall SVC example*

Significant contribution to the damping of Queensland New South Wales Interconnector (QNI) interarea oscillations is from the three PODs implemented on the SVCs in South East Queensland (Greenbank, South Pine and Blackwall). Frequency input POD controllers are applied across all South East Queensland SVCs. A similar technical solution is applied on some SVCs in South Australia. Frequency input into POD controller for all mentioned SVCs is measured locally, usually at the low voltage side of the SVC transformer by the PLL (phase-locked loop) used by the SVC control system for firing of the thyristor. A PMU (phasor measurement unit – synchrophasor) based system is used for the on-line monitoring of the small signal stability in the Australian power system. It has been observed that the frequency measured by the PLL and PMU is highly sensitive to the fast changes of the voltage. The discrepancies in the frequency measurement are a major contributor to the significant discrepancies between the measured and simulated output of SVCs. Due to the discrepancies Powerlink performed several tests on the SVCs in South East Queensland. Results of the investigation and some conclusions related to different methods used for frequency measurement will be presented.

## DR YINAN GENG

**Tsinghua University, China**
gengyinan@tsinghua.edu.cn

Yinan Geng received his bachelor's degree and PhD degree in electrical engineering from Tsinghua University in 2006 and 2011 respectively. Since then, he has been an Associate Professor of Tsinghua University Institute of Energy Internet Innovation. He has long been engaged in long air gap discharge and electromagnetic transient measurement. Since 2006, he has researched the integrated optical electric field sensor and its application in long air gap discharge, for example electric field measurement. He presided over and participated in a number of 973 issues, the national science and technology support program and the National Natural Science Foundation of China. Since 2016, he has developed transient voltage monitoring system based on integrated optical electric field sensor. One type transient voltage monitoring system has been developed and installed in the 220kV and 110kV substations and transmission lines in Sichuan and Guangdong to monitor lightning or switching overvoltage.

### *Transient voltage and current measurement and stability and security analysis for power transmission and distribution system*

Power grid voltage and current are important parameters for the safe and stable operation of power systems. The monitoring of grid voltage and current is done through the voltage transformer (PT) and current transformer (CT). However, the traditional PT and CT have some shortcomings, such as covering large areas volume and limited frequency band, and thus cannot achieve effective measurement of voltage and current transient waveform in time domain. The development of advanced sensing technology, represented by integrated optics technology, is feasible for monitoring transient voltage and current parameters of the power grid. In the substation (station) or on the transmission line voltage, synchronous measurement of the grid parameters can be achieved in steady state and transient voltage and current from DC to 100MHz frequency range. The measurement results of for the steady-state parameters can be comparable with the traditional PT and CT signal, or even replace the traditional PT and CT, which will save space and simplify the substation layout and enable data analysis technology based on through analysis of transient signal waveform, harmonic analysis and implementation of traceability, fault location and distance, lightning location and other functions. An advanced sensor technology grid transient parameter monitoring system enables the monitoring of the key parameters of the voltage and current is expanded from measuring traditional single steady state signals to measuring the transient changes based on the waveform analysis. This change will fundamentally change the power grid operation state monitoring to ensure safe and stable operation of power grid based decision making.

## DR JARI HÄLLSTRÖM

**VTT Technical Research Centre of Finland Ltd**
jari.hallstrom@vtt.fi

Jari Hällström received his MSc and DSc degrees in electrical engineering from the Helsinki University of Technology, Espoo, Finland, in 1987 and 2002, respectively. Until 2008 he held various positions with the Helsinki University of Technology, where his first research interest was instrumentation for the measurement of magnetic fields of the human brain, and later high-voltage metrology. Since 2008, he has been with the Centre for Metrology, VTT Technical Research Centre of Finland, Espoo, where he is currently a Senior Scientist working on electrical metrology. Dr. Hällström received the IEC 1906 Award in 2007 for his work on standardization of high-voltage measuring techniques.

### *Experience with high voltage and smart grid related European metrology projects*

This presentation briefly describes ongoing European Union-funded metrology programs EMRP and EMPIR, running from 2007 to 2024. Most of the highlights of European research in electrical metrology during the last decade have resulted from numerous joint research projects funded by the EU. An overview of high voltage and smart grid related projects is given, as well as information on current open calls and possibilities for non-European participation. Key results of some power grid related projects are shown, with emphasis on presentation of the joint development of a modular 1000 kV HVDC reference voltage divider.

## PROFESSOR XINGHUO YU

**RMIT University, Australia**
x.yu@rmit.edu.au

Professor Xinghuo Yu is Associate Deputy Vice-Chancellor (Research Capability) and Distinguished Professor at RMIT University, Melbourne, Australia, He is also President-Elect (2016-2017) of the Institute of Electrical and Electronics Engineers (IEEE) Industrial Electronics Society.

His main research areas are control engineering, intelligent systems, and smart grids. He received a number of awards and honours for his contributions, including the 2013 Dr Ing Eugene Mittelmann Achievement Award from the IEEE Industrial

Electronics Society. He was named a 'Highly Cited Researcher' by Thomson Reuters in 2015 and 2016. He is a Fellow of the IEEE, Institution of Engineering and Technology (UK), Australian Computer Society, Engineers Australia, and Australian Institute of Company Directors. He was also a Changjiang Scholar Chair Professor of Southeast University, Nanjing, China.

### *Smart grid and beyond–towards a socio-cyber-energy future*

Smart grids are electric networks that use innovative and intelligent monitoring, control, communication, and self-healing technologies to deliver better connections and operations for generators and distributors, flexible choices for prosumers, and reliability and security of electricity supply. In this talk, I will present an overview of the recent developments in Smart grids. Some of our recent work will be shown as case studies. Furthermore, we will examine the global trend and challenges in Smart grid and beyond, advocating a more holistic view towards energy supply, transport and use, a socio-cyber-energy future.

## DR ILYA BUDOVSKY

**National Measurement Institute of Australia (NMIA)**
ilya.budovsky@measurement.gov.au

Dr Ilya Budovsky heads the Electricity Section at the National Measurement Institute of Australia (NMIA). He is responsible for the development and dissemination of Australian physical standards of measurement for electricity, time and frequency. He also leads the Energy Sector Focus Team that aims at engaging with the Australian energy sector and raising the impact of measurements in the sector. Dr Budovsky is a Fellow of Engineers Australia, Senior Member of IEEE, the Australian representative to the Consultative Committee for Electricity and Magnetism and Chair of NATA's Accreditation Advisory Committee on Calibration.

### *Measurements underpinning electrical energy security in Australia and planning for the workshop*

Every day millions of measurements are performed in the electricity grid to ensure its reliable operation and trade of electrical energy. Linking these measurements to internationally recognised physical standards of measurement is essential in ensuring secure supply of energy to households and businesses in both Australia and China and its trade. This presentation is an overview of the work at the National Measurement Institute of Australia to establish traceable high-precision measurements of electrical quantities at low and high voltages and disseminate them to Australian and Chinese industries.

# WELCOME AND INTRODUCTION
# TO THE NATIONAL MEASUREMENT INSTITUTE OF AUSTRALIA (NMIA)


## DR LINDSEY MACKAY

**General Manager**
**National Measurement**
**Institute of Australia (NMIA)**
lindsey.mackay@measurement.gov.au


Lindsey has been the General Manager of the National Measurement Institute of Australia's Chemical and Biological Metrology Branch, and a member of the NMIA executive since 2009. She has responsibility for the development and maintenance of Australia's chemical and biological measurement standards. Until recently, she has also been the chair of NMIA's Strategy and Policy Subcommittee that oversees the work of four sector teams, on energy, environment, food and health. The Sector Teams are responsible for cross-organisational engagement with the sector stakeholders in government, industry and community.

## ABOUT THE NMIA

The National Measurement Institute of Australia (NMIA) is Australia's'one-stop shop' for measurement and sits at the peak of Australia's measurement system. Through the breadth of its activities, it helps to realise the potential of measurement to enhance Australia's economic prosperity and well-being.

NMIA's measurement expertise, infrastructure, standards and services are simultaneously world-class and practically oriented. It develops and maintains Australia's primary measurement standards to deliver internationally recognised measurement services to Australian industry covering collaborations, reference chemicals, chemical and biological analyses such as food and environmental testing, sports drug and forensic drug testing, and training in specific measurement techniques. It also provides support and advice on measurements made for legal purposes; assists industries to develop new measurement methods and administers Australia's national trade measurement system.

NMIA comprises a multidisciplinary team of about 350 people across Australia who deliver practical measurement solutions to help address Australia's societal and economic challenges in areas including health, environment, energy, food and agriculture, security and trade. NMIA works collaboratively with researchers and industry to support Australia's competitive edge using measurement to improve productivity through enhanced process efficiency and control, waste reduction and product research, development and optimisation.

# BREAKOUT SESSIONS | GROUP 1: POWER QUALITY

## TUESDAY, 5 SEPTEMBER

| | |
|---|---|
| 14.45 | **Risk assessment and reserve requirements for power systems with high wind power penetration**<br>**Professor Michael Negnevitsky**<br>University of Tasmania, Australia |
| 15.15 | **Afternoon tea** |
| 15.45 | **Establishment of power standard at frequencies up to 100 kHz**<br>**Dr Jiangtao Zhang**<br>National Institute of Metrology (NIM) China |
| 16.15 | **Harmonic power standard at NIM and its compensation algorithm**<br>**Mr Lei Wang**<br>National Institute of Metrology (NIM) China |
| 16.45 | **Battery evaluations for electrical energy storage**<br>**Mr Simon Troman**<br>ITP Renewables, Australia |

## THURSDAY, 7 SEPTEMBER

| | |
|---|---|
| 9.00 | **Management of microgrids and technical challenges**<br>**Dr Farhad Shahnia**<br>Murdoch University, Australia |
| 9:30 | **Design and implementation of differential AC voltage sampling system based on PJVS**<br>**Dr Zhengsen Jia**<br>National Institute of Metrology (NIM) China |
| 10.00 | **Calibration and potential application of PMUs**<br>**Dr Dimitrios Georgakopoulos**<br>National Measurement Institute of Australia (NMIA) |
| 10.30 | **Morning tea** |
| 11.00 | **Synchrophasor technology for real-time stability monitoring and control**<br>**Dr Lasantha Meegahapola**<br>RMIT University, Australia |
| 11.30 | **A white rabbit synchronised PMU**<br>**Dr Behrooz Bahrani**<br>Monash University, Australia |

# CHAIRS

## DR DIMITRIOS GEORGAKOPOULOS

**National Measurement Institute of Australia (NMIA)**
dimitrios.georgakopoulos@measurement.gov.au

Dimitrios Georgakopoulos received his B.Eng. degree in electrical engineering from the Technological Educational Institution of Piraeus, Egaleo, Greece, in 1996; his M.Sc. degree in electronic instrumentation systems from the University of Manchester, Manchester, UK, in 1999; and his Ph.D. in electrical engineering and electronics from the University of Manchester, Institute of Science and Technology, Manchester, UK, in 2002. From 2002 to 2007, he worked as a research scientist at the National Physical Laboratory, UK. In 2007, he joined the National Measurement Institute of Australia (NMIA) as a research scientist, where he has been working on the development of quantum electrical standards and low frequency electromagnetic compatibility (EMC) standards. Dr Georgakopoulos is Chair of the Technical Committee of the Asia-Pacific Metrology Program (APMP) for harmonics, flicker, phase and charge measurements; a member of the Accreditation Advisory Committee (AAC), calibration, for the National Association of Testing Authorities (NATA), Australia; Associate Editor of the Institute of Electrical and Electronics Engineers (IEEE) Transactions on Instrumentation and Measurement; a member of the Measurements in Power Systems IEEE committee (TC-39); and a member of the American Association for the Advancement of Science (AAAS), USA.

## DR JIANGTAO ZHANG

**National Institute of Metrology (NIM) China**
zhangjt@nim.ac.cn

Jiangtao Zhang received his BS and MS degrees in electrical engineering from Changchun Geological Institute, Changchun, China, in 1993 and 1996 and his PhD degree from Jilin University, Changchun, China, in 2014. In 1996, Dr Zhang joined the National Institute of Metrology (NIM) China, where he was involved in the research of AC-DC transfer measurements and power measurements. Since 2000, he has been the head of the AC quantities laboratories of NIM. His interest is currently in high frequency power measurement.

# PRESENTERS

## PROFESSOR MICHAEL NEGNEVITSKY

**University of Tasmania, Australia**
michael.negnevitsky@utas.edu.au

Michael Negnevitsky received his BSEE and PhD degrees from Byelorussian University of Technology, Minsk, Belarus in 1978 and 1983 respectively.
He worked at the Electrical Maintenance, Construction and Commissioning Company in Minsk as an electrical engineer, and then became a Senior Research Fellow and Senior Lecturer in the Department of Electrical Engineering, Byelorussian University of Technology, Minsk. Professor Negnevitsky then joined Monash University and the University of Tasmania. In 2006, he was appointed Professor, Chair in Power Engineering and Computational Intelligence, Director of the Centre for Renewable Energy and Power Systems. He has been the key member of the research team that has generated a research income of over $4 million. From 2006 he has been Adjunct Full Professor in the School of Engineering, University of Vermont, Burlington, USA. In 2014 he was appointed Honorary Professor of Shandong University of Science and Technology, China for 'outstanding achievements and contributions made to the cooperation between Shandong University of Science and Technology and University of Tasmania'. Professor Negnevitsky has authored and co-authored more than 400 refereed research publications including 91 journal papers, more than 300 conference papers, 12 chapters in books, two books, eight edited conference proceedings and received four patents for inventions.

### *Risk assessment and reserve requirements for power systems with high wind power penetration*

Integration of wind power generation is increasing rapidly worldwide. The variability and uncertainty of wind energy may lead to significant load-generation imbalances resulting in large frequency deviations, increasing system operational risks, especially in small and isolated power systems with low inertia and limited capabilities of providing frequency responses. Traditionally security assessment is performed based on deterministic criteria, but the deterministic method may no longer be adequate for modern power systems with market driven dispatch and high penetration of renewable energy and distributed generation. PV and wind power generation (WPG) increase uncertainties, requiring new security assessment methods. This presentation proposes a risk assessment approach to the quantitative evaluation of security of power systems with significant WPG for short-term operation planning. The proposed risk assessment approach is concerned with steady-state voltage and overload evaluations, and frequency response adequacy. The system operational risk is defined as the product of probability and severity of the system failure states in terms of expected load interruption cost (ELIC) taking into account the randomness of contingencies as well as the uncertainty of operating conditions caused by load and WPG forecasting errors.

## DR JIANGTAO ZHANG

**National Institute of Metrology (NIM) China**
zhangjt@nim.ac.cn

Jiangtao Zhang received his BS and MS degrees in electrical engineering from Changchun Geological Institute, Changchun, China, in 1993 and 1996 and his PhD degree from Jilin University, Changchun, China, in 2014. In 1996, Dr Zhang joined the National Institute of Metrology (NIM) China, where he was involved in the research of AC-DC transfer measurements and power measurements. Since 2000, he has been the head of the AC quantities laboratories of NIM. His interest is currently in high frequency power measurement.

### *Establishment of power standard at frequencies up to 100 kHz*

This presentation describes the wideband power standard for traceable measurements of electrical power of sinusoidal signals. The voltage ranges from 10 V to 600 V and the current ranges from 1 A to 100 A at frequencies up to 100 kHz. A set of resistive voltage dividers and current shunts were designed and calibrated in amplitude errors and phase angle errors. An accurate dual-channel digitiser was introduced and its relationship of two channels in phase angle errors was also measured at working frequencies.

## DR FARHAD SHAHNIA

**Murdoch University, Australia**
f.shahnia@murdoch.edu.au

Farhad Shahnia received his PhD in electrical engineering from Queensland University of Technology (QUT), Brisbane in 2012. He is currently a Senior Lecturer at the School of Engineering, Murdoch University, Perth. Before that, he was a Lecturer at Curtin University, Perth (2012–15), a research scholar at QUT (2008–11), and an R&D engineer at Eastern Azarbayjan Electric Power Distribution Company, Iran (2005–08). Dr Shahnia's research falls under operation and control of distribution networks, smart grids and microgrids. He has edited six books, and has authored 10 book chapters and over 100 peer-reviewed scholarly articles in international conferences and journals. Three of his conference papers won the Best Paper Awards at IEEE conferences, and he received the IET Premium Award for his paper in the IET Generation, Transmission & Distribution journal in 2015. One of his articles was listed under the top-25 most cited articles in the Electric Power System Research journal in 2015 while one of his 2015 journal articles was listed under the top-5 most read articles of the Australian Journal of Electrical and Electronics Engineering. He was the recipient of Curtin Postgraduate Research Supervisor Award in 2014 and the Australia–China Young Scientist Exchange Award in 2016.

### *Management of microgrids and technical challenges*

Ever-growing electricity demand, along with the requirement for cost reduction and higher reliability, are driving modern power systems towards distributed energy resources (DER) as an alternative to the expansion of the electricity distribution networks. Microgrids are systems with clusters of DERs, battery energy storages (BESs) and loads. To deliver power with high quality and reliability, microgrids should be controllable and respond promptly to changes in the system. Microgrids can operate in a grid-connected mode as well as an autonomous (islanded) mode during network maintenance or fault conditions. In grid-connected mode, the grid dictates the voltage and frequency of the network and the DERs operate at their nominal or maximum power points, while in autonomous mode the DERs share the load demand. Power sharing among parallel DERs can be achieved by droop control to resemble the power sharing among generators in a conventional power system. As a third alternative to the operation of microgrids, two or more neighbouring microgrids can be coupled provisionally when one experiences overloading or excessive generation from its renewable energy-based DERs instead of load-shedding and renewable curtailment. This is a more viable option for large remote areas in which their system can be in the form of a group of adjacent microgrids. This presentation focuses on introducing microgrids, their operation principles and technical challenges, corresponding control principles, and the necessity of data measurement and transfer to realise their smooth dynamic operation.

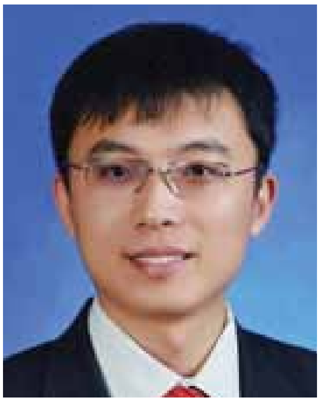
## MR LEI WANG

**National Institute of Metrology (NIM) China**
wl@nim.ac.cn

Lei Wang received his Master's degree from the National Institute of Metrology (NIM) China in 2001. Since 1996, he has been with the Electromagnetic Division, NIM. His research activity has been focused on the development of systems and procedures in the field of power and energy measurements. His current main interests are in sampling technology, voltage harmonic, current harmonic and power harmonic measurements, and in the generation, acquisition and reconstruction of electrical signals.

### *Harmonic power standard at NIM and its compensation algorithm*

A new harmonic power standard has been developed at the National Institute of Metrology (NIM) China for the calibration of harmonic power analysers under nonsinusoidal conditions at fundamental frequencies of 50 and 60 Hz. The standard is based on digital sampling techniques that do not require synchronisation. A compensation algorithm is presented. A new definition of the uncertainty for harmonic measurement is proposed where the uncertainty is referred to the fundamental. A characterisation signal and its application are introduced. Results have shown that over its operating range of up to 50 A, 500 V, and the sixtieth-order harmonic, the harmonic power standard has uncertainties ($k = 2$) of less than 30 μV/V, 36 μA/A, and 42 μW/VA for voltage, current and power measurements, respectively.



## DR ZHENGSEN JIA

**National Institute of Metrology (NIM) China**
jiazs@nim.ac.cn

Zhengsen Jia joined NIM in 2015. Since then he has worked on establishing the Chinese AC power differential sampling system based on the AC programmable Josephson voltage standard. At the same time, he helped industry to solve some precise measurement problems, such as drive circuit design of PJVS, and the signal process of the differential sampling measurement principle. His current research interest is to evaluate the uncertainty of the differential sampling system.

### *Design and implementation of differential AC voltage sampling system based on PJVS*

In this presentation a differential sampling measurement principle is introduced, then based on this principle, it is described how a precision differential sampling system is developed to measure sine-wave sources with the use of a quantum-accurate AC programmable Josephson voltage standard, and how switching measurement technology is adopted in the differential sampling system design. By analysing the error source of the differential sampling system, a mathematical model is established and the error transfer function is derived. A variety of measurements were performed to evaluate this differential sampling system. Firstly, the basis of FLUKE 5720A transition process is analysed, and the selection scheme of the sampling window is described. After averaging, the uncertainty obtained in the determination of FLUKE 5720A 1 V RMS amplitude sine wave at 60 Hz is 0.3 μV/V (type A), the uncertainty obtained in the determination of PJVS 1 V RMS amplitude sine wave at 60 Hz is 0.05 μV/V (type A).

## DR DIMITRIOS GEORGAKOPOULOS

**National Measurement Institute of Australia (NMIA)**
dimitrios.georgakopoulos@measurement.gov.au

Dimitrios Georgakopoulos received his B.Eng. degree in electrical engineering from the Technological Educational Institution of Piraeus, Egaleo, Greece, in 1996; his M.Sc. degree in electronic instrumentation systems from the University of Manchester, Manchester, UK, in 1999; and his Ph.D. in electrical engineering and electronics from the University of Manchester, Institute of Science and Technology, Manchester, UK, in 2002.

From 2002 to 2007, he worked as a research scientist at the National Physical Laboratory, UK. In 2007, he joined the National Measurement Institute of Australia (NMIA) as a research scientist, where he has been working on the development of quantum electrical standards and low frequency electromagnetic compatibility (EMC) standards.

Dr Georgakopoulos is Chair of the Technical Committee of the Asia-Pacific Metrology Program (APMP) for harmonics, flicker, phase and charge measurements; a member of the Accreditation Advisory Committee (AAC), calibration, for the National Association of Testing Authorities (NATA), Australia; Associate Editor of the Institute of Electrical and Electronics Engineers (IEEE) Transactions on Instrumentation and Measurement; a member of the Measurements in Power Systems IEEE committee (TC-39); and a member of the American Association for the Advancement of Science (AAAS), USA.

### *Calibration and potential application of PMUs*

Phasor Measurement Units (PMUs) are precision electrical measuring instruments used in Wide Area Monitoring Systems for monitoring the state of smart grids. They are considered to be one of the most important elements in the power networks of the future. Distributed PMUs are synchronised to Coordinated Universal Time (UTC) by timing signals derived from a Global Positioning System (GPS) clock. Evaluation studies of PMUs have shown the importance of traceable measurements in assuring reliability, model-to-model interchangeability and consistency of the measurements across the power industry. The PMU measurement requirements are described in IEEE Std C37.118.1. This documentary standard requires the calibration device used to verify the performance of a PMU to be traceable to the national measurement standards. The National Measurement Institute has developed a facility for the calibration of PMUs, traceable to the Australian national standards of measurement. This presentation covers the measurement techniques and the algorithms used, the operation and evalutation of the system, the traceability issues to the SI units, and the uncertainty analysis for the quantities of interest. The potential applications of PMUs are also discussed.

## DR LASANTHA MEEGAHAPOLA

**RMIT University, Australia**
lasantha.meegahapola@rmit.edu.au

Lasantha Meegahapola is with the School of Engineering, RMIT University, Australia. He received BSc Eng degree in electrical engineering from the University of Moratuwa, Sri Lanka in 2006, and his PhD degree from the Queen's University of Belfast, UK in 2010. Dr Meegahapola was a Visiting Researcher/Post-Doctoral Researcher at the Electricity Research Centre (ERC), University College Dublin, Ireland (2009–10). From 2011–14 he was employed as a Lecturer at the University of Wollongong (UOW) and continue as an Honorary Fellow. He has conducted extensive research studies in power system stability with renewable power integration during last 10 years, and has published more than 70 journal and conference articles. Dr Meegahapola is a Senior Member of IEEE (SMIEEE) and Member of IEEE Power Engineering Society (PES). He is an active member of the IEEE PES Power System Dynamic Performance (PSDP) committee working group on voltage stability and the task force on microgrid stability analysis and modelling.

### *Synchrophasor technology for real-time stability monitoring and control*

Electricity networks are rapidly transforming with the wide-scale integration of variable renewable energy sources. The variability of renewable sources has resulted in rapid changes in the electrical parameters, and hence the present power grid is more vulnerable to instability issues. The conventional supervisory control and data acquisition (SCADA)-based measurement and monitoring network is becoming obsolete as a robust monitoring tool for transforming electricity networks, and a more vigorous measurement and monitoring network is required to maintain grid stability. The synchrophasor technology offers significant advantages over existing SCADA technology, since each measurement is time-stamped based on a GPS synchronised clock, and hence it provides more reliable and accurate data to determine the state of the power grid.
A synchrophasor measurement network could be used as a reliable network for measurement and control of the transforming power network to maintain network stability and security. However, more research is required to efficiently use synchrophasor technology for power system stability monitoring and control. This presentation outlines various algorithms that have been used for real-time stability monitoring using the synchrophasor data and their applications in real power networks. It also highlights the areas which require further attention from the power engineering community for future research.

## DR BEHROOZ BAHRANI

**Monash University, Australia**
behrooz.bahrani@monash.edu

Behrooz Bahrani received his BSc degree from Sharif University of Technology, Iran, his MSc degree from the University of Toronto, Canada, and his PhD degree from the Ecole Polytechnique Federale de Lausanne (EPFL), Switzerland, all in electrical engineering, in 2006, 2008, and 2012 respectively. From 2012 to 2015 he was a Postdoctoral Fellow at several institutions including EPFL, Purdue University and Georgia Institute of Technology, USA, and Technical University of Munich, Germany. Currently, He is currently a Lecturer at Monash University. His research interests include control of power electronics systems, applications of power electronics in power and traction systems, and grid integration of renewable energy resources.

### *A white rabbit synchronised PMU*

The distributed measurement of synchrophasors via phasor measurement units (PMUs) represents one of the most advanced sensing layers in the domain of wide area monitoring and control (WAMC) systems. According to the IEEE Std. C37.118.1-2011, a PMU is a measurement device synchronised to a common coordinated universal time (UTC) reference, which reports phase-aligned and time-stamped measurements of frequency, amplitude and phase angle of the voltage and current phasors of a power system. In general, the time synchronisation of PMUs relies on the global positioning system (GPS) as it represents a good tradeoff between performance and cost. However, its main drawbacks are accuracy, accessibility and security. In particular, GPS might not provide a stable and reliable time reference especially in cases where underground substations, with limited or no access to the sky, need to be equipped with PMUs. Therefore, a more suitable time dissemination technique, deployable over the legacy power system's telecom infrastructure, might be required. In addition, recent works have shown that, since civilian GPS satellite signals are not authenticated, they can be spoofed by superimposing a fake signal with a higher signal-to-noise ratio, which would enable an attacker to manipulate the GPS clock. Among the possible alternatives to the GPS, the white rabbit (WR) represents an excellent candidate as time synchronisation protocol in view of its superior peculiarities. The WR is a low-latency, time-deterministic ethernet-based network time dissemination technique, developed for distributed sensing systems. In this presentation, a specific PMU integrating the WR technology will be presented.

# BREAKOUT SESSIONS | GROUP 2: MEASUREMENT OF POWER QUANTITIES IN ELECTRICAL GRIDS

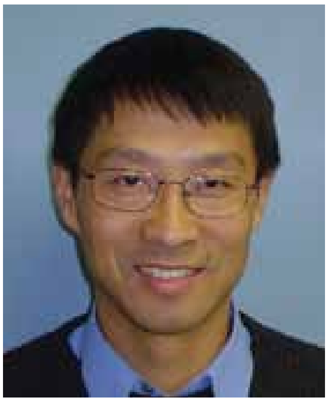
## TUESDAY, 5 SEPTEMBER

| | |
|---|---|
| 14.45 | **Technology and application of fibre-optic current transformer**<br>**Dr Chuansheng Li**<br>National Institute of Metrology, China |
| 15.15 | **Afternoon tea** |
| 15.45 | **Dynamic measurement for DC electrical energy**<br>**Mr Yue Liu**<br>National Institute of Metrology (NIM) China |
| 16.15 | **Interactions between Indirect dc-voltage estimation and circulating current controllers of MMC-based HVDC transmission systems**<br>**Dr Georgios Konstantinou**<br>UNSW Sydney, Australia |
| 16.45 | **Measuring LV power line impedances from 4kHz to 20 MHz on-line**<br>**Associate Professor Cornelis Kikkert**<br>University of Adelaide, Australia |

## THURSDAY, 7 SEPTEMBER

| | |
|---|---|
| 9.00 | **Coupled-mode optical waveguide sensors—applications in electrical measurement**<br>**Professor Graham Town**<br>Macquarie University, Australia |
| 9.30 | **The measurement system for steep impulse testing of polymeric high-voltage insulators**<br>**Dr Yi Li**<br>National Measurement Institute of Australia (NMIA) |
| 10.00 | **Calibration of test system for measuring power loss**<br>**Dr Wei Zhao**<br>National Institute of Metrology (NIM) China |
| 10.30 | **Morning tea** |
| 11.00 | **Magnetic property measurement of magnetic powder core**<br>**Mr XinHua Zhou**<br>Tunkia Co. Ltd, China |

# CHAIRS



## DR YI LI


**National Measurement Institute of Australia (NMIA)**
yi.li@measurement.gov.au


Yi Li is the head of the high-voltage laboratory at the National Measurement Institute of Australia (NMIA). The laboratory is responsible for the development, maintenance and dissemination of national measurement standards for high-voltage and high-current related quantities in Australia. The laboratory disseminates these standards through calibration and training services. The laboratory also provides high-voltage testing services to industry. Dr Li is the team leader of two IEC TC42 working groups, responsible for maintenance of IEC Standards, IEC 60060-2 High-Voltage Testing Techniques - Part 2: Measuring Systems and IEC 61083-1 Instruments and software used for measurements in high-voltage and high-current tests – Part 1: Requirements for instruments for impulse tests. Dr Li is also the convenor of the CIGRE WG D1.60, on Traceable measurement techniques for very fast transients.

## DR WEI ZHAO


**National Institute of Metrology (NIM) China**
zhaowei@nim.ac.cn


Dr Wei Zhao received his B.S. and Ph.D. degree in instrument science and technology from Tianjin University in 2006 and 2012 respectively. He is now with the National Institute of Metrology (NIM) China. He developed an integrated frequency detecting system based on software phase-locked loop for MEMS resonant sensor in 2014, and finished research of power calibration for high frequency electro-surgical analyser in 2016. His current work mainly focuses on high-voltage metrological technology. He is working on the lightning impulse voltage calibration standard and preparing an international comparison on 700 kV lightning impulse measuring ability which should be finished in 2018. He is also leading a Chinese National Quality Infrastructure project which focuses on power calibration at low power factors.

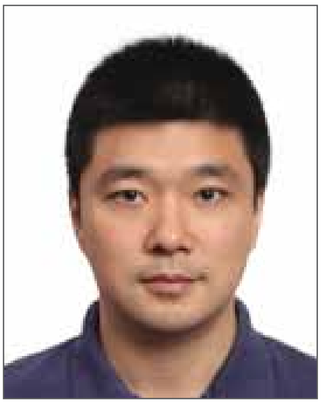
## DR CHUANSHENG LI

**National Institute of Metrology (NIM) China**
lichsh@nim.ac.cn

Chuansheng Li received his BE degree in instrument science and technology from China University of Mining and Technology, Beijing, in 2006 and his PhD degree in optical engineering from Beihang University, Beijing, in 2013. From 2013 to 2015 he investigated the fibre-optic current and voltage sensing technology at the Smart Grid Research Institute affiliated to the State Grid Corporation of China. He is currently working at the National Institute of Metrology (NIM) China. His research interests have included the wideband large current metrology technology and fibre-optic current sensing technology.

### *Technology and application of fibre-optic current transformer*

In this presentation, a fibre-optic current sensor (FOCS) based on the Faraday effect is proposed for the direct high current measurement application such as electro-winning industry. The current-induced magneto-optic phase is detected by means of an in-line Sagnac interferometer. The digital closed-loop signal-detecting scheme is utilised to improve the linearity of the sensor. The spun high birefringence optical fiber with strong resistance to external stress perturbations is packed into a flexible sensing element, which can be coiled without opening the current-carrying bus bar. The FOCS achieves accuracy within ±0.2% in the range between 10kA and 120kA, and is used for the online metrology of rectification efficiency.



## MR YUE LIU

**National Institute of Metrology (NIM) China**
liuyue@nim.ac.cn

Yue Liu works in the division of electromagnetism of the National Institute of Metrology (NIM) China, as an associate researcher. His focus is the research of DC voltage ratio calibration and AC small current calibration for multi-meters. Since electrical vehicles are developing rapidly in China, he is working on the development of a DC electrical energy standard to calibrate both DC electrical energy and dynamic electrical energy.

### *Dynamic measurement for DC electrical energy*

With the rapid development of China's economy, including more power consumption, DC electric energy measurement is coming into an urgent need in fields such as DC EHV transmission, electric vehicles and high-speed rail. But the development of the instrument or standard for DC power calibration has not kept up with the demand. Large DC power is usually superimposed by some AC components. The signal to be measured is dynamic and irregular, and the actual requirement of DC power and dynamic energy detection is different from the traditional detection method for steady-state signal, so that the static detection method is hard to improve accuracy. Considering the characteristics and measurement requirements, a high-speed sampling method is adopted to get all the original information of the input signal and then obtain the time domain information (including integration, correction, synchronisation and ratio) by real-time hardware operation. As a result, as long as the rate of data acquisition is high enough, the original information will quickly approach the actual measured signal, and the dynamic signal detection is far superior to the traditional energy measurement which is achieved depending on the average value of the signal. The data acquisition rate is 20 kHz, equivalent to 400 times the power frequency harmonics, which can meet the requirements of the measurement of DC power and dynamic energy. If more rapid signal acquisition capability is needed, the sampling rate can be increasing by decreasing the dynamic significant bit.

## DR GEORGIOS KONSTANTINOU

**UNSW Sydney, Australia**
g.konstantinou@unsw.edu.au

Georgios Konstantinou is a lecturer at the School of Electrical Engineering and Telecommunications at UNSW Sydney, and an ARC Discovery Early Career Research (DECRA) Fellow. His main research interests are power electronics (topologies, operation and control) for HVDC and high power applications, the interaction of power electronics with AC networks, renewable energy and energy storage systems. Dr Konstantinou received his PhD in 2012 from UNSW Sydney in electrical engineering. He was with the School of Electrical and Information Engineering at the University of Sydney from 2008 to 2010, a Research Associate and a Senior Research Associate with the Energy Research Institute at UNSW Sydney from 2012 and 2015 respectively. He was part of the Australia–China Young Scientist Exchange Program in 2015 and 2016. He has authored more than 35 journal and 55 international conference articles and is an Associate Editor in major power electronics journals (IEEE and IET Transactions).

### *Interactions between indirect dc-voltage estimation and circulating current controllers of MMC-based HVDC transmission systems*

This presentation is based on our recent publication (June 2017) where we investigate DC voltage estimation methods for HVDC systems. Estimation-based indirect dc-voltage control in MMCs interacts with circulating current control methods. We propose an estimation-based indirect dc-voltage control method for MMC-HVDC systems and analyse its performance compared to alternative estimation methods. The interactions between estimation-based indirect dc-voltage control and circulating current control methods, active/reactive power regulation are also investigated. The proposed method delivers similar performance to measurement-based direct dc-voltage control, regardless of the circulating current control method. Steady-state and transient performance is demonstrated using a benchmark MMC-HVDC transmission system, implemented in a real-time digital simulator (RTDS). The presented results verify the theoretical evaluations and illustrate the operation and performance of the proposed indirect dc-voltage control method.

## ASSOCIATE PROFESSOR CORNELIS KIKKERT

**University of Adelaide, Australia**
keith.kikkert@adelaide.edu.au

Cornelis Jan (Keith) Kikkert has more than 40 years of lecturing and research experience in electronic instrumentation for communication and power systems. His research area for the last 15 years is the measurement of power line characteristics for smart grid power line communications (PLC) and using on-line PLC frequency measurements to detect developing faults in transformers and motors.

Associate Professor Kikkert has written more than 100 peer reviewed research papers, one book and four book chapters, and is the inventor on eight patents or patent applications.

### *Measuring LV power line impedances from 4kHz to 20 MHz on-line*

Power line carrier (PLC) communications is often used for smart grid communications. To design efficient PLC couplers, the impedance of the power line must be known. The inductive shunt on-line impedance analyser (ISOIA) and the resistive shunt on-line impedance analyser (RSOIA) both allow such impedances to be measured. This presentation describes the design principles of and the differences between the ISOIA and the RSOIA. Both can measure on-line impedances as well as sub-mains-cycle variations in on-line impedances. The RSOIA also allows on-line transfer functions to be measured. The ISOIA covers the 10 kHz to 5 MHz frequency range and the RSOIA covers the 4 kHz to 20 MHz frequency range. Examples of measurements of power lines, transformers and induction motors are presented. These show that developing faults can be detected by on-line PLC frequency measurements, before any catastrophic failures occur. This presentation includes a live measurement demonstration using the RSOIA.

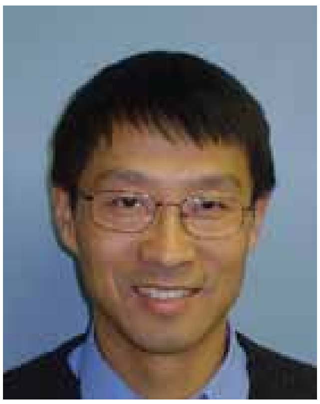
## PROFESSOR GRAHAM TOWN

**Macquarie University, Australia**
graham.town@mq.edu.au

Graham Town is an electrical engineer with eight years' experience in the Australian electronics industry, and 30 years' experience in engineering education and research. He received a BE in electrical engineering from NSWIT (now UTS) in 1984, a PhD in medical imaging from the University of Sydney in 1992, and a Graduate Certificate in Leadership and Management (Higher Education) from Macquarie University in 2007. Professor Town is currently a Professor in the Department of Engineering at Macquarie University where he established Macquarie University's undergraduate engineering program, first offered in 2004. His research and teaching have been in diverse areas including optical communications and sensing technology and systems, biomedical engineering, and engineering education. In recent years has been leading industry-supported research projects on power electronics for compact and efficient power converters and inverters, and smart grids with a focus on electric vehicle integration and energy management.

### *Coupled-mode optical waveguide sensors—applications in electrical measurement*

The transmittance of microstructured coupled waveguide arrays, in either of fibre or in planar form, strongly depends on the coupling between the waveguides. If the host material, and/or a material introduced between the coupled waveguides, has a refractive index which depends on the parameter being sensed (e.g. electric field, temperature) then it is possible to realise distributed optical sensors with the benefits of very high sensitivity and/or a large dynamic range in a single device. The principles of coupled-mode waveguide sensors will be presented, together with examples of microstructured optical waveguides designed for measuring electric field, pressure, etc.



## DR YI LI

**National Measurement Institute of Australia (NMIA)**
yi.li@measurement.gov.au

Yi Li is the head of the high-voltage laboratory at the National Measurement Institute of Australia (NMIA). The laboratory is responsible for the development, maintenance and dissemination of national measurement standards for high-voltage and high-current related quantities in Australia. The laboratory disseminates these standards through calibration and training services. The laboratory also provides high-voltage testing services to industry. Dr Li is the team leader of two IEC TC42 working groups, responsible for maintenance of IEC Standards, IEC 60060-2 High-Voltage Testing Techniques - Part 2: Measuring Systems and IEC 61083-1 Instruments and software used for measurements in high-voltage and high-current tests – Part 1: Requirements for instruments for impulse tests. Dr Li is also the convenor of the CIGRE WG D1.60, on Traceable measurement techniques for very fast transients.

### *The measurement system for steep impulse testing of polymeric high-voltage insulators*

The steep impulse test is one of the important tests for ensuring the quality of high-voltage polymeric insulators. Poor adhesion at the interface between the insulator core and the insulator sheds causes partial discharge at the interface, which can lead to electrical breakdown of the insulator during service. The steep impulse test is used to expose the faulty interface to avoid the potential failure of the insulator during the service. The effectiveness of this test depends on the steepness of the impulse voltage applied to the test sample. The rate of rise of the impulse applied to the test sample needs to be greater than 1000 kV/μs according to relevant international standards. Measuring such fast impulses with peak voltages that often exceeds 1000 kV presents challenges. The presentation discusses the performance of the steep impulse measurement system developed by the National Measurement Institute of Australia (NMIA) and experience of its use in performing the steep impulse tests.

## DR WEI ZHAO

**National Institute of Metrology (NIM) China**
zhaowei@nim.ac.cn

Dr Wei Zhao received his B.S. and Ph.D. degree in instrument science and technology from Tianjin University in 2006 and 2012 respectively. He is now with the National Institute of Metrology (NIM) China. He developed an integrated frequency detecting system based on software phase-locked loop for MEMS resonant sensor in 2014, and finished research of power calibration for high frequency electro-surgical analyser in 2016. His current work mainly focuses on high-voltage metrological technology. He is working on the lightning impulse voltage calibration standard and preparing an international comparison on 700 kV lightning impulse measuring ability which should be finished in 2018. He is also leading a Chinese National Quality Infrastructure project which focuses on power calibration at low power factors.

### *Calibration of test system for measuring power loss*

For clinical applications, according to IEC 60601-2-2, power calibration up to 1 MHz is required for electrosurgical units (also referred to as electrosurgical generators), electrosurgical analysers and accessories. Traceability in the case of high frequencies in combination with power up to 400 W has not been addressed before, especially when the voltage is as high as 400 V, and the load impedance is between 200 and 500. This presentation discusses a reference system which was built for power calibration of electrosurgical analysers in the frequency range between 100 kHz and 1 MHz. Measurements of the individual components required to calibrate analysers in this range are described. The principle behind the system is based on the calibration of the analyser input impedance and the voltage. A high frequency power source was developed to generate high power for the electrosurgical analyser. A low dissipation capacitive voltage divider was developed for high frequency voltage calibration. With frequency response calibration of the low range and nonlinearity calibration of the high range of the voltmeter, calibration of the high frequency voltmeter up to 400 V was realised. A summary of the uncertainty components at 1 MHz condition is presented. The expanded uncertainty (k=2) of the power calibration at 1 MHz is approximately 1.3 %, which satisfies the requirements for commercial electrosurgical analysers  Magnetic property measurement of magnetic powder core

Magnetic powder core is widely used in power electronics. It's a kind of inductive material, with frequency range of 40Hz~200kHz. Its relative permeability is between 10 and 100, and the loss angle is close to 90 degrees, while the typical value is 89.8 degrees. It's concluded that phase error of 0.1 degrees will lead to 50% deviation of the loss. Accordingly the loss measurement is very difficult. This presentation describes some of the research we have done to solve this problem and some of the preparation of relevant IEC standards.

## MR XINHUA ZHOU

**Tunkia Co. Ltd. China**
zhouxh@tunkia.com.

XinHua Zhou received his BS degree in electronic information from Tianjin University in 1990. He founded Tunkia Co. Ltd in 2006, working in electromagnetic measurement research and led the team to develop electrical measurement and magnetic measurement of two kinds of products, including high-precision AC and DC measurement, multifunction calibrator, three phase electricity standard, basic magnetic measurement, magnetic materials measurement and magnetic components measurement.

# BREAKOUT SESSIONS | GROUP 3: STORAGE

## THURSDAY, 7 SEPTEMBER

| | |
|---|---|
| **9.00** | **Development of new energy electric appliances and the demand for electric metering in the energy internet**<br>**Mr Zhigang Zhao**<br>GREE, China |
| **9.30** | **A multi-agent simulation framework for distributed generation with battery storage**<br>**Dr Peter Sokolowski**<br>RMIT University, Australia |
| **10.30** | **Morning tea** |

# CHAIRS

## DR LEIGH JOHNSON

**National Measurement Institute of Australia (NMIA)**
leigh.johnson@measurement.gov.au

Leigh Johnson is the team leader for Impedance Standards at the National Measurement Institute of Australia (NMIA). The team is responsible for the development, maintenance and dissemination of national measurement standards in Australia for resistance, capacitance, inductance and voltage ratio, by providing calibration services to industry.
The team leads an international collaboration to build a new generation of calculable cross-capacitors, to realise the Farad with unprecedented accuracy.

## DR PETER SOKOLOWSKI

**RMIT University, Australia**
peter.sokolowski@rmit.edu.au

Peter Sokolowski is a Research Fellow with RMIT University and manages the Information Systems Engineering Research Group. His career interest is in bringing industry, research, education and professional bodies together to collaborate for the benefit of the whole community. He was with BHP Steel, Newcastle, Australia for five years and ESCAPE Technologies Pty Ltd for fourteen years consulting to the manufacturing industry on industrial electrical power distribution, information and communication technology and issues in the area of electrical energy including distribution services, policy and contracts.
Dr Sokolowski's research interests include modelling, condition monitoring, system performance health measurement, control, optimisation of systems (such as nonlinear, hybrid, electrical power and biological systems) and analytics where knowledge-based engineering provides decision support.
He is a Fellow of Engineers Australia, a Senior Member of IEEE and a Member of the Electric Energy Society of Australia (EESA). He is currently a Member of the Engineers Australia Electrical College Board and the 2017 Engineers Australia Electrical College Victoria Branch Chair. He is also a Member of EESA's National Council and Deputy Chair of its Victorian Chapter.

# PRESENTERS

## MR ZHIGANG ZHAO

**GREE, China**
travois.zhao@163.com

Zhigang Zhao is the Deputy Director of the State Key Laboratory of Air Conditioning Equipment and System Operation Energy Saving. He has been engaged in motor frequency control, DCS control system and information technology and DC micro-network and new energy DC electrical research for 15 years. He participated in the implementation of the industry's first permanent magnet synchronous frequency conversion centrifuge project, leading demonstration and implementation of the photovoltaic direct drive variable frequency centrifuge system project results for the world's first, leading international and 2016 British refrigeration RAC annual achievement award.

***Development of new energy electric appliances and the demand for electric metering in the energy internet***

The emerging energy internet requires multi-source hybrid energy production to implement 'multi-source complementary' energy supply from the horizontal sources, and ensure utilisation of renewable energy as a priority. Each link of the 'generation-grid-load-energy storage' scheme must be implemented in a highly coordinated way in the vertical direction. For distributed energy and power consumption equipment to be utilised seamlessly, distributed energy generation must combine with power consuming equipment to provide a cleaner and more efficient new energy supply mode, while facilitating a series of new electrical appliances supplied with clean energy. Directing usage of DC power of this new type will become a key technology in this link. This presentation compares the new energy electrical devices, and the research hotspots of DC system application at home and abroad. It analyses the direction in the development of existing technology and the feasibility of the new technology application. It proposes the development of distributed energy and electric devices with a gradual trend to DC. DC micro networks and DC power distribution systems consisting of a DC power supply, energy storage, loads and monitoring devices will become important in the field of power supply in the future. Electric energy metering is the 'access key' of energy systems, however, the current electric energy metering system is just AC energy metering. The development of DC electric energy metering is imperative to implement collaborative interaction between information and energy under the new energy internet.

## DR PETER SOKOLOWSKI

**RMIT University, Australia**
peter.sokolowski@rmit.edu.au

Peter Sokolowski is a Research Fellow with RMIT University and manages the Information Systems Engineering Research Group. His career interest is in bringing industry, research, education and professional bodies together to collaborate for the benefit of the whole community. He was with BHP Steel, Newcastle, Australia for five years and ESCAPE Technologies Pty Ltd for fourteen years consulting to the manufacturing industry on industrial electrical power distribution, information and communication technology and issues in the area of electrical energy including distribution services, policy and contracts. Dr Sokolowski's research interests include modelling, condition monitoring, system performance health measurement, control, optimisation of systems (such as nonlinear, hybrid, electrical power and biological systems) and analytics where knowledge-based engineering provides decision support. He is a Fellow of Engineers Australia, a Senior Member of IEEE and a Member of the Electric Energy Society of Australia (EESA). He is currently a Member of the Engineers Australia Electrical College Board and the 2017 Engineers Australia Electrical College Victoria Branch Chair. He is also a Member of EESA's National Council and Deputy Chair of its Victorian Chapter.

### *A multi-agent simulation framework for distributed generation with battery storage*

Distributed generation (DG) is a sustainable alternative energy paradigm that allows flexible customer-participated demand response management, high penetration of renewable sources and reduction of greenhouse gas emission. This presentation proposes a multi-agent simulation framework that captures emerging complex responses that originate from individual household behaviours. These behaviours have been unattainable with traditional top-down simulation frameworks. The simulation results demonstrate a suboptimal policy choice may lead to unwanted energy profile responses on the distribution network.

## THURSDAY, 7 SEPTEMBER

| | |
|---|---|
| **9.00** | **Big data management of future smart grids**<br>**Dr Ghassem Mokhtari**<br>CSIRO, Australia |
| **9.30** | **Key technology and application of energy measurement data security**<br>**Mr Wenhan Zhang**<br>China Electric Power Research Institute (CEPRI) of SGCC , China |
| **10.00** | **A smart meter error measurement method using consumption data analysis**<br>**Dr Fangxing Liu**<br>Harbin Institute of Technology and National Institute of Metrology (NIM) China |
| **10.30** | **Morning tea** |
| **11.00** | **IoT-based energy and environment management in smart buildings**<br>**Associate Professor Quang Ha**<br>University of Technology Sydney, Australia |

# CHAIRS

## DR QING HE

**National Institute of Metrology (NIM) China**
heqing@nim.ac.cn

Qing He is the director of Electricity and Magnetism Division, NIM. He joined NIM in 1988. From then to 2003, he worked on establishing the Chinese QHR standard based on a cryogenic current comparator. At the same time, he helped industry to solve some precise measurement problems, such as low magnetic flux and permeability of soft magnetic material. He developed a method to measure mutual inductance by using a digital integrator, which became the technical basis of the Chinese Joule Balance. His current research interests are to evaluate the uncertainty of smart meters on site by means of big data, the metrological service for smart grid, and the electrical vehicle charger.

## MR LOUIS MARAIS

**National Measurement Institute of Australia (NMIA)**
louis.marais@measurement.gov.au

Louis Marais joined the National Measurement Institute of Australia (NMIA) in 2007 as an electrical metrologist. In 2013 he moved to the time and frequency laboratory. The laboratory is responsible for the development, maintenance and dissemination of the national measurement standards for time and frequency in Australia. These standards are disseminated through provision of calibration and training services. Louis' main responsibility is the development of time transfer systems. He is the coordinator of the Working Group of the Mutual Recognition Agreement (MRA) of the Technical Committee on Time and Frequency (TCTF) in the Asia Pacific Metrology Programme (APMP). Before joining the NMIA he was with the National Metrology Institute of South Africa for 14 years.

# PRESENTERS

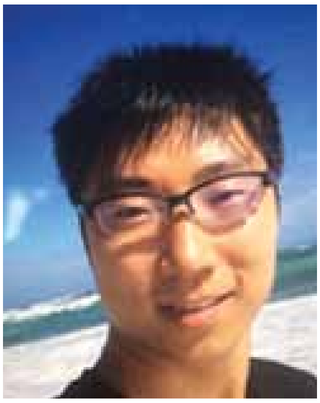
## DR GHASSEM MOKHTARI

**CSIRO, Australia**
ghassem.mokhtari@csiro.au

Ghassem Mokhtari received his PhD degree from Queensland University of Technology (QUT) in 2014. As a PhD student, he won several scholarships and awards including QUTPRA scholarship, SEF Faculty top-up award and outstanding higher degree research student award. He then joined Avicenna Ltd, a medical company, as an electrical engineer, with his work including medical hardware (wireless medical devices) and software (mobile applications) developments. Dr Mokhtari is now with CSIRO's Australian e-Health Research Centre as a postdoc fellow with his main focus on smart home technologies and applications. He is also serving as webmaster of IEEE Queensland section and Secretary of IEEE QLD EMB chapter.

### *Big data management of future smart grids*

The advances in digital technologies and internet of things (IOTs) have caused a tremendous increase in the volume of data generation. The high volume of data needs proper management and processing. Smart grids are one the main hosts of digital technologies and IOT devices, and future smart grids will also face the issue of big data. Thanks to advances in data storage and processing technologies, it is now feasible to use these capabilities and achieve benefits from different big data driven decision making within smart homes. This presentation will present a new smart grid architecture that can deal with big data generation and processing.



## MR WENHAN ZHANG

**China Electric Power Research Institute (CEPRI) of SGCC, China**
dasweida1218@hotmail.com

Wenhan Zhang's main research interests are advanced metering infrastructure, inspection and testing, smart grid and power system automation.

### *Key technology and application of energy measurement data security*

Energy measurement data are the basic data sources of designing smart cities and realising energy conservation and emission reduction. The promotion and application of big data, cloud computing, internet of things (IoT) and mobile internet technology are driving the rapid development of energy measurement, and are also bringing serious challenges for the security of measurement data. This presentation introduces the structure of the energy measurement data system and analyses the current situation and application demands for the system at home and abroad. It focuses on the basic and forward-looking technologies necessary for future energy measurement development, such as new-generation cryptographic technology, private information protection in energy information network environments, the distribution and application mode of quantum key, secure communication protocol, big data access control, information sharing and fusion, and mass data processing, analysing and application. The application of all these key technologies in China can provide the basic scientific basis for developing the top-level design and deepening applications of the energy measurement system.

## DR FANGXING LIU

**Harbin Institute of Technology and National Institute of Metrology (NIM) China**
liufx@nim.ac.cn

Fangxing Liu received his MS degree in instrumentation science and technology from Harbin Institute of Technology, Harbin, China, in 2015. He is currently working toward his PhD as a joint doctoral student with Harbin Institute of Technology and National Institute of Metrology (NIM) China. His research focuses on smart grid systems and big data analytics.

### *A smart meter error measurement method using consumption data analysis*

In recent years, with the smart grid implementation, especially the advanced metering infrastructure implementation, a large amount of smart meter data has been collected in the data centres of many provincial power companies in China. Smart meters can immediately monitor the entire system. To discover the potential value of these valuable data resources has been the focus of both academic and industrial fields. This presentation introduces a methodology to compute smart meter errors based on the consumption data from smart meters. We try to solve a linear system equation to get each meter error. Abnormal data comes from faulty meters and abnormal consumption behavior such as electricity theft will greatly affect the linear equations. So the data pre-processing method is based on orthogonal matching pursuit algorithm and regression theory to find the abnormal data. In order to obtain better results, we propose an algorithm based on regularisation theory to solve the equations. Some simulations are carried out and results show the performance of the method. The method has the potential usage of power grid equipment fault detection and gives a smart meter replacement strategy to power enterprises.

## ASSOCIATE PROFESSOR QUANG HA

**University of Technology Sydney, Australia**
quang.ha@uts.edu.au

Quang Ha received the BE degree from Ho Chi Minh City University of Technology, Vietnam, in 1983, his PhD degree from Moscow Power Engineering Institute, Russia, in 1993, and his PhD degree from the University of Tasmania, Australia, in 1997, all in electrical engineering. He is currently an Associate Professor and Deputy Head of School (Research) of Electrical, Mechanical, and Mechatronic Systems, University of Technology Sydney, Australia. His research interests include automation, robotics, control, and computational intelligence. Associate Professor Ha is a Senior Member of the IEEE and on the Board of Directors of the International Association of Automation and Robotics in Construction. He has been a Member of the Editorial Board of the IEEE Transactions on Automation Science and Engineering (2009–13), Automation in Construction, Mathematical Problems in Engineering, International Journal of Automation and Control, and Journal of Advanced Computational Intelligence and Intelligent Informatics. Quang Ha was the Chairman of 2 International Conferences on automation and intelligent systems. He was the recipient of 14 best paper awards from the IEEE, IAARC and Engineers Australia, including the Sir George Julius Medal in 2015.

### *IoT-based energy and environment management in smart buildings*

Fast urbanisation requires a new generation of buildings, for which reliable and resilient management of energy and emissions poses scientific challenges. A microgrid integrating various sources of distributed generation, especially renewable energy sources, is promising to supply power for green buildings or in the case of an emergency and power shortage.

To achieve energy efficiency and provide a healthy living environment for occupants it is essential to understand the energy functioning and interacting with the building environment. This presentation introduces a control and monitoring system for energy and building services as well as indoor air quality. The focus is on optimisation of the building energy cost and the development of dependable controllers that integrate real-time modelling, robust predictive control and estimation into an internet-of-things to optimally manage energy flows in buildings as well as monitor their environmental interactions, and thus to illustrate digital intelligence in building energy management.

# NOTES