PhD-Level Short Course:
Advanced Modelling of DER-Rich Active Distribution Networks

Course information

Monday 23th – Friday 27th May 2022

THE UNIVERSITY OF MELBOURNE

Power and Energy Systems Group

Melbourne Energy Institute

About the short course

The short course on Advanced Modelling of DER-Rich Active Distribution Networks covers fundamental and advanced modelling of active distribution networks with deep penetration of distributed energy resources (DER).

The short course on *Advanced Modelling of DER-Rich Active Distribution Networks* is a five day PhD-level course delivered by the Power and Energy Systems Group and the Melbourne Energy Institute (MEI) at the University of Melbourne. After successfully being held for the first time in 2021 with over 1000 participants, this course will again be offered fully online in 2022.

The short course covers fundamental and advanced modelling of active distribution networks with deep penetration of distributed energy resources (DER). Topics discussed will include power flow and optimal power flow algorithms suitable for diverse applications of active distribution networks with DER, consideration for uncertainty arising from renewables, provision of flexibility and grid services from DER, distributed multi-energy systems and community energy systems, and fundamentals of distributed energy markets.

COURSE DELIVERY

The course will be delivered fully online from **Monday 23rd to Friday 27th May 2022**.

Live lectures will also be recorded so that they can be accessed by individuals in different time zones.
All live and recorded lectures and the corresponding material will be accessible via the Learning Management System “Canvas”.

COST

This course is being offered free of charge.

CONTACT

For further information, please visit the MEI website or contact the Melbourne Energy Institute at mei-info@unimelb.edu.au.

APPLICATIONS

Applicants are requested to click *APPLY NOW* and complete the form. Applications close on 19th May 2022.

Apply now >

DATES AND INSTRUCTORS	
Monday 23rd May	Prof. Steven Low
Tuesday 24th May	Prof. Steven Low
Wednesday 25th May	Dr. Maria Vrakopoulou
Thursday 26th May	Prof. Nando Ochoa
Friday 27th May	Prof. Pierluigi Mancarella

TIMES (MELBOURNE TIME, AEST)	
4 lecture blocks (approximately 55 min of lecture time including Q&A and small break)	
Block 1:	8:30am-9:30am
Block 2:	9:30am-10:30am
30 minute break	
Block 3:	11:00am-12:00pm
Block 4:	12:00pm-1:00pm

Monday 23rd May: Unbalanced 3-phase models and analysis

Professor Steven Low

Block 1. Single-phase model and optimal power flow	
	Power flow models: Y matrix, AC power flow, DC power flow;
	OPF: QCQP, polar form, non-convexity, NP hardness;
	Example applications: unit commitment, optimal dispatch, security constrained OPF
Block 2. Unbalanced 3-phase models	
	Mathematical properties;
	Model overview;
	Component models: Y configuration, Delta configuration, 3-phase lines;
	Network models: V-I relationship, V-s relationship
Block 3. Unbalanced 3-phase analysis	
	Overall model and unbalanced 3-phase analysis
	Balanced network: per-phase networks; per-phase analysis
	Symmetric network: symmetrical components, sequence networks
Block 4. Unbalanced 3-phase OPF	
	3-phase devices;
	3-phase OPF as QCQP;
	Examples

Professor Steven Low
Gilloon Professor, *Caltech*
Honorary Professor, *The University of Melbourne*

Prof. Low is the Gilloon Professor of Engineering and Applied Science at Caltech and an Honorary Professorial Fellow of the EEE Department at the University of Melbourne. His current research focuses on power systems and has made an impact in both academia and industry. He is a Fellow of IEEE and ACM and has been awarded the 2021 IEEE INFOCOM Achievement Award and the 2021 ACM SIGMETRICS Test of Time Award. Read more about Prof. Low.

Tuesday 24th May: Branch Flow Models (BFM), properties of OPF relaxations

Professor Steven Low

Block 1. Branch flow models for radial networks	
	DistFlow equation and generalizations;
	Forward-backward sweep methods;
	Linear DistFlow: analytical properties;
	Application: volt/var control
Block 2. OPF in BFM and relaxations	
	Single-phase: OPF, SOCP relaxation;
	Unbalanced 3-phase: OPF, chordal relaxation
Block 3. Analytical properties of relaxations: single-phase	
	SDP relaxations, chordal relaxation, SOCP relaxation;
	Equivalence and exactness;
	Local algorithms attaining global optimality
Block 4. Analytical properties of relaxations: unbalanced 3-phase	
	Exactness condition: bus injection model;
	Exactness condition: branch flow model

Wednesday 25th May: Decision-Making Under Uncertainty due to Renewables

Dr. Maria Vrakopoulou

Block 1. Renewable energy integration challenges

- Review of dynamic operation, equilibrium points
- Ancillary services
- Forecast errors and power flows

Block 2. Stochastic OPF with approximate solutions

- Classic stochastic formulations
- Chance-constrained and robust OPF
- The scenario optimization

Block 3. Stochastic OPF with AC-feasible solutions

- AC-QP, SDP OPF reformulations
- The non-convex scenario optimization

Block 4. Co-optimization of energy and reserves

- Control policies for reserve deployment
- Reserves from thermostatically controlled loads
- Aggregated storage dynamics
- Pricing impact

Thursday 26th May: Orchestration of Distributed Energy Resources (DER) and Active Distribution Networks

Professor Nando Ochoa

Block 1. The role and challenges of OPF in distribution

- From fit and forget to Active Networks to DER orchestration
- **Opportunities, modelling challenges, and practical aspects**

Block 2. OPF and DER-rich distribution networks

- DER orchestration and hosting capacity calculations using OPF
- Interactive session using an OPF tool developed in AIMMS

Block 3. DER and network integrity: Meter-level operating envelopes

- Concept of operating envelopes, calculations and challenges
- Case study and lessons learned: Project EDGE

Block 4. The electrical model-free future

- Capturing the physics of LV networks from smart meter data
- Case study and lessons learned: Project "Model-Free Operating Envelopes at NMI Level"

Dr Maria Vrakopoulou
Lecturer in Power Systems
The University of Melbourne

Dr. Maria Vrakopoulou is a Lecturer (Assistant Professor) in the Power and Energy Systems Group at the University of Melbourne. She obtained her Ph.D. degree from ETH Zurich, Switzerland, and then pursued her research as a post-doc at the University of Michigan, Ann Arbor, USA for a year. Maria was then also awarded a three-year Marie Curie post-doctoral fellowship to join the University of California, Berkeley, USA, and ETH Zurich, Switzerland. Read more about Dr. Vrakopoulou.

Professor Nando Ochoa
Professor of Smart Grids and Power Systems
The University of Melbourne

Prof. Nando Ochoa is a Professor of Smart Grids and Power Systems at the Department of Electrical and Electronic Engineering. He is an IEEE PES Distinguished Lecturer, an Editorial Board Member of the IEEE Power and Energy Magazine, and an IEEE Senior Member. From 2011 to 2021, Prof. Ochoa worked with The University of Manchester, UK. Prior to this he was a Research Fellow in Energy Systems at the University of Edinburgh, UK. Read more about Prof. Ochoa.

Friday 27th May: DER Flexibility and Techno-Economic Modelling

Professor Pierluigi Mancarella

Block 1. Modelling flexibility from DER aggregation
Power system flexibility and role of DER
Characterization of DER flexibility
DER flexibility metrics and maps
OPF methodologies to build flexibility maps

Block 2. Flexibility from distributed multi-energy systems: smart buildings, energy communities and microgrids
Multi-energy DER and multi-energy node concept
Multi-energy flexibility maps
Modelling of buildings and community-level DER
Energy communities and microgrids

Block 3. Distributed energy marketplaces and grid services
Aggregators and Virtual Power Plants
Distribution System Operator (DSO) and distributed energy markets
Value stack by co-optimised provision of local and system-level services
Value mapping methodologies and business case opportunities for different stakeholders

Block 4. Tutorial with illustrative case studies from ongoing and recent projects (delivered by Dr Shariq Riaz, University of Melbourne)
DER flexibility maps: technical and commercial applications
Flexibility from integrated electricity-heat systems
Flexibility from hydrogen electrolysers
Techno-economic modelling of urban virtual power plants

Professor Pierluigi Mancarella
Chair of Electrical Power Systems, and Program Leader Energy Systems, Melbourne Energy Institute
The University of Melbourne

Prof. Pierluigi Mancarella is the Chair Professor of Electrical Power Systems at the University of Melbourne, Australia, and Professor of Smart Energy Systems at the University of Manchester, UK. He obtained the MSc and PhD degrees from the Politecnico di Torino, Italy, did his post-doc at Imperial College London, UK, and has held several visiting positions, including NREL, Colorado, Ecole Centrale de Lille, France, Universidad de Chile, and Tsinghua University, China. He is an IEEE PES Distinguished Lecturer and an Editor in several prestigious journals.
Read more about Prof. Mancarella.

For more information, visit electrical.eng.unimelb.edu.au/power-energy or energy.unimelb.edu.au

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