European Control Conference 2016
Full-Day Pre-Conference Workshop

Optimization and Control for Tomorrow's Power Systems

Goal of the Workshop

The workshop provides a broad and profound overview of recent developments in different areas of power systems optimization and control for both newcomers to and experts in this field.

Abstract

The increasing penetration of distributed and renewable generators into today's power systems poses new challenges to power system management and control. Future power system management systems have to balance the mismatch between volatile renewable generation and load as well as to bridge the geographical gap between renewable generators and load centers. For power system modeling, analysis and control, the mathematical and physical fundamentals of state-of-the-art methods have to be questioned in general, because these methods rely on power supply through synchronous generators and most renewable generators are connected to the power system with power electronic converters.

The workshop provides a broad and profound overview of recent developments in different areas of power system modeling, analysis, optimization and control. The major topics are economic dispatch and unit commitment, power flow optimization, power system stability and control, as well as modeling and control of power electronic converters. For each topic, selected experts give plenary talks on their recent findings. We aim at a stimulating and interactive environment leaving plenty of time for discussions so that workshop attendees are able to discuss the presented results with the speakers.

Motivation for this Workshop

Optimization and control of power systems has received a steadily increasing attention in the control systems community, e.g. *smart grid* was among the top key words of the IFAC World Congress 2014. Even though the topic has already achieved a high publication rate, our community is still far from building up a new methodological kernel that is required to build up efficient power system management and control systems. The workshop aims at stimulating the discussion and collaboration between experts as well as at providing an introduction to newcomers to this field.

Intended audience and prerequisites

The workshop is intended both for experts in and newcomers to this field. It provides a unique opportunity to get a broad and profound overview of recent developments in all fields of power system control and optimization as well as to have a close interaction with the presenters. A basic knowledge of electrical engineering and power systems will be helpful to understand the underlying models. However, it is not required to understand the control and optimization concepts.

Agenda

Time	Speaker	Topic
09:00 – 09:15	Organizers	General introduction
09:15 – 10:00	Marco Cupelli	From the converter to the cloud: challenges in the automation architecture of future power systems
Economic Dispatch and Unit Commitment		
10:00 – 10:45	Chenye Wu	Challenges and solutions: what innovations in optimization are needed in the future electric power systems?
10:45 – 11:00	break	
11:00 – 11:45	Na Li	Load management using supply function bidding
Power Flow Optimization		
11:45 – 12:30	Ulrich Münz	Robust optimal power flow for power systems with volatile renewable generation
12:30 – 13:30	lunch break	
Power System Stability and Control		
13:30 – 14:15	Johannes Schiffer	On control concepts for microgrids
14:15 – 15:00	Florian Dörfler	Virtual inertia emulation and placement in power grids
15:00 – 15:15	break	
Modeling and Control of Power Electronic Converters		
15:15 – 16:00	Francesco Vasca	Advanced modeling of power converters: complementarity switchings and averaged discontinuities
16:00 – 16:45	Remus Teodorescu	Control challenges for modular multilevel converter (MMC) in HVDC applications
16:45 – 17:00	Organizers	Closing

List of speakers and abstracts

Marco Cupelli: From the converter to the cloud: challenges in the automation architecture of future power systems

Automation of Power Systems is a field currently in a rapid evolution. The need of finding new ways to incorporate Distributed Energy Resources is stimulating the studies of new architecture and solutions. The presentation will give an overview of the major trends that are driving these changes. In particular, the link between the need of modern power systems and the availability of new ICT solutions will be considered. The analysis of the emerging options and solutions will be supported with examples coming from real life application in the framework of national and EU level projects.

Marco Cupelli received the Diplom Wirt.-Ing. from the Technische Universität Darmstadt, Germany, in 2008. He then worked for a consulting company. He has been in the Institute of Automation of Complex Power Systems, E.ON Energy Research Center, RWTH Aachen University, Aachen, Germany, since 2009, where he currently performs as Team Leader of the Group - Control of Special Purpose Grids. He received his Dr.Ing Degree from RWTH Aachen University in 2015. His current research interests include stability issues in distribution networks, microgrids, and DC networks.

Chenye Wu: Challenges and solutions: What innovations in optimization are needed in the future electric power systems?

The key task of the electric power systems operator is to balance generation and load at all times. This is currently being done by scheduling generation ahead of time at different time intervals, e.g. day ahead and hour ahead, using economic dispatch and a real time balancing achieved by frequency control. As the penetration of renewable generation grows, this task is becoming increasingly difficult due to the inherent variability and uncertainty of these resources. Increased deployment of demand response programs and distributed storage provide additional capacities to balance the variability and intermittency but overall the dispatch optimization is becoming more challenging. New tools and approaches are needed not only to solve the resulting optimization problems but also to find formulations which allow capturing the characteristics of the future electric power grid, e.g. the uncertainty in generation resources. Hence, this talk will provide an overview over state of the art approaches in the generation and load balancing process, discuss issues that arise from these approaches in the future electric power system and propose directions and potential solutions.

Chenye Wu is currently a postdoctoral fellow at ETH Zurich, and he is going to join IIIS, Tsinghua University, as an Assistant Professor in Dec. 2016. He received the doctoral degree in Computer Science from IIIS, Tsinghua University, in July 2013, under the supervision of Prof. Andrew Yao. After his PhD graduation, Dr. Wu first joined the ECE department, Carnegie Mellon University as a postdoc in 2013 for one year, hosted by Prof. Gabriela Hug and Prof. Soummya Kar. From 2014 to 2016, Dr. Wu was a postdoctoral researcher at University of California, Berkeley, hosted by Prof. Kameshwar Poolla and Prof. Pravin Varaiya from 2014 to 2016. He was the best paper award co-recipients of IEEE SmartGridComm 2012, and the best of best paper award co-recipients of IEEE PES General Meeting 2013. Currently, he is working on the optimization, distributed control and game-theoretic analysis of power systems and electricity market.

Na Li: Load management using supply function bidding

In the power grid, load management has been increasingly used to improve the energy efficiency and system reliability. One major challenge is the market design to incentivize the large number of loads to coordinate. In this talk, we consider abstract market models for load management where a supply function bidding is applied to match power supply deficit or surplus. We will discuss two different types of supply function. For both of them, we characterize the resulting equilibria in competitive and oligopolistic markets and analyze the efficiency of the equilibria. Basically, we show that the equilibrium in competitive market maximizes social welfare, and the equilibrium in oligopolistic market has bounded efficiency loss under certain mild assumptions. We also propose distributed demand response algorithms to achieve the equilibria.

Na Li is an assistant professor in Electrical Engineering and Applied Mathematics of the School of Engineering and Applied Sciences in Harvard University since 2014. She received her PhD degree in Control and Dynamical systems from California Institute of Technology in 2013 and was a postdoctoral associate of the Laboratory for Information and Decision Systems at Massachusetts Institute of Technology. Her research lies in the design, analysis, optimization and control of distributed network systems, with particular applications to power networks and systems biology/physiology. She entered the Best Student Paper Award finalist in the 2011 IEEE Conference on Decision and Control.

Ulrich Münz: Robust optimal power flow for power systems with volatile renewable generation

The increasing integration of distributed and renewable generators into existing power systems poses new challenges to power system management, control, and protection. In this presentation, new methods for robust power flow optimization are presented that address some of these challenges. First, the methodological background is explained. Second, its usage is discussed along different fields of applications. Third, concrete examples are used to illustrate the numerical complexity.

Ulrich Münz is a senior key expert research scientist for power system stability and control at Siemens Corporate Technology in Munich, Germany. He received his Ph.D. degree in Automatic Control from the University of Stuttgart, Germany in 2010 and MSc degrees in Electrical Engineering and Telecommunications from the Universities of Stuttgart, Germany, and Madrid, Spain, both in 2005. From 2010 to 2011 he was a systems engineer at Robert Bosch GmbH. His research interests include the analysis of and controller design for large scale systems like power systems. He received the EECI European PhD Award on Embedded and Networked Control in 2010.

Johannes Schiffer: On control concepts for microgrids

The microgrid represents one promising solution to facilitate the integration of large shares of renewable energy sources into the electrical grid. The present talk covers several aspects of the operation of microgrids and introduces relevant control problems in such networks. In particular, main operation modes of inverter-interfaced generation units are reviewed and a model of a microgrid is presented. Furthermore, three important performance criteria in such networks are introduced, namely frequency stability, voltage stability and power sharing. Control schemes to address these problems are discussed. The analysis is illustrated via simulation examples of a microgrid based on the CIGRE benchmark medium voltage distribution network.

Johannes Schiffer is a Lecturer in Smart Energy Systems at the School of Electronic & Electrical Engineering, University of Leeds, UK. He received his Ph.D. degree (Dr.-Ing.) in Electrical Engineering from TU Berlin, Germany, in 2015 and a Diploma degree in Engineering Cybernetics from the University of Stuttgart, Germany, in 2009. Prior to joining the University of Leeds, he has held appointments as research associate in the Control Systems Group (2011 - 2015) and at the Chair of Sustainable Electric Networks and Sources of Energy (2009 - 2011) both at TU Berlin. He has been involved in several research projects in the areas of modeling, control and analysis of future power systems with industrial partners including Boeing Commercial Airplanes, Siemens AG, Skytron AG, Vattenfall AB and Vattenfall Europe as well as Younicos AG. In 2008/09, he has been a visiting student at Lund University, Sweden.

During 2008 he was involved in the design and construction of a prototype of a solar updraft tower at Fundacion Palma, Chile in cooperation with Schlaich, Bergermann and Partner (sbp), Germany.

Florian Dörfler: Virtual inertia emulation and placement in power grids

A major transition in the operation of electric power grids is the replacement of bulk generation based on synchronous machines by distributed generation based on low-inertia power electronic sources. The accompanying "loss of rotational inertia" and the fluctuations by renewable sources jeopardize the system stability, as testified by the ever-growing number of frequency incidents. As a remedy, numerous studies demonstrate how virtual inertia can be emulated through various devices, but few of them address the question of "where" to place this inertia. It is however strongly believed that the placement of virtual inertia hugely impacts system efficiency, as demonstrated by recent case studies. We carry out a comprehensive analysis in an attempt to address the optimal inertia placement problem, considering a linear network-reduced power system model along with an H2 performance metric accounting for the network coherency. The optimal inertia placement problem turns out to be non-convex, yet we provide a set of closed-form global optimality results for particular problem instances as well as a computational approach resulting in locally optimal solutions. We illustrate our results with a three-region power grid case study and compare our locally optimal solution with different placement heuristics in terms of different performance metrics.

Florian Dörfler is an Assistant Professor at the Automatic Control Laboratory at ETH Zürich. He received his Ph.D. degree in Mechanical Engineering from the University of California at Santa Barbara in 2013, and a Diplom degree in Engineering Cybernetics from the University of Stuttgart in 2008. From 2013 to 2014 he was an Assistant Professor at the University of California Los Angeles. His primary research interests are centered around distributed control, complex networks, and cyber–physical systems currently with applications in energy systems and smart grids. His students were finalists for Best Student Paper awards at the European Control Conference (2013) and the American Control Conference (2016). His articles received the 2010 ACC Student Best Paper Award, the 2011 O. Hugo Schuck Best Paper Award, and the 2012-2014 Automatica Best Paper Award. He is a recipient of the 2009 Regents Special International Fellowship, the 2011 Peter J. Frenkel Foundation Fellowship, and the 2015 UCSB ME Department Best PhD award.

Francesco Vasca: Advanced modeling of power converters: Complementarity switchings and averaged discontinuities

A typical approach for the analysis of power electronics converters consists of assuming idealized characteristics of the electronic switches. This approach yields to the important advantage that details of the device behavior do not eclipse the basic operation of the circuit, making easier the analysis and, sometimes, reducing the computational load for numerical simulations. Ideal characteristics of the switching devices allow to model power electronic converters as switched systems. Indeed, the network evolves through multiple topologies (or modes) depending on the discrete states of the switching devices (conducting or blocking). Unfortunately, also in open loop operating conditions, commutations of the electronic switches can depend on the state variables and the switched model eventually becomes rather complex also for simple converter topologies. In general a switched model that describes all possible operating conditions is very difficult to be constructed also for converters with

few electronic devices. Complementarity and averaged models represent attractive solutions to obtain compact models of power converters and to simplify their analysis, respectively. In this presentation it will be shown how the complementarity approach can be used to represent open-loop and closed-loop power converters, and to compute the typical cyclic steady state behavior of switched electronic systems. Moreover it will be also shown how the classical averaging approach can be extended to the case of modes represented by differential algebraic equations and in the presence of state jumps.

Francesco Vasca received the Ph.D. in Automatic Control from the University of Napoli Federico II in 1995. Since 2000 he is professor at the University of Sannio (Benevento, Italy), currently as Full Professor of Automatic Control. His research activity is focused on the analysis and control of switched systems with applications to power electronics, railway control, automotive control and, more recently, social networks. From 2008 to 2014 he served as Associate Editor for the IEEE Transactions on Control Systems Technology. He is an IEEE Senior Member since 2012.

Remus Teodorescu: Control challenges for modular multilevel converter (MMC) in HVDC applications

Modular Multilevel Converter (MMC) technology is emerging on the market of high power applications. Due to the multidimensional character given by the number of submodules in each arm (N) the control becomes more complex than the traditional control of two-level converters. The presentation will make an overview of the new control aspects which are necessary in the control structure of MMC: distributed control architecture based on communication, non-linear modulation and cell energy balancing methods based on sorting and selection as well as FPGA implementation.

Remus Teodorescu received the Dipl.Ing. degree in electrical engineering from Polytechnical University of Bucharest, Romania in 1989, and PhD. degree in power electronics from University of Galati, Romania, in 1994. In 1998, he joined Aalborg University, Department of Energy Technology, where he currently works as a professor. Since 2013 he is a visiting professor with Chalmers University of Technology, Division of Electric Power Engineering. He is a Fellow Member of IEEE. His areas of interests are: MMC, HVDC/FACTS, HV SiC MosFet, design and control of power converters for wind power systems and PV, energy storage systems based on Li batteries.