

PROCEEDINGS

# 6<sup>th</sup> Solar Integration Workshop

International Workshop on Integration  
of Solar Power into Power Systems



14 - 15 November 2016 | Vienna, Austria

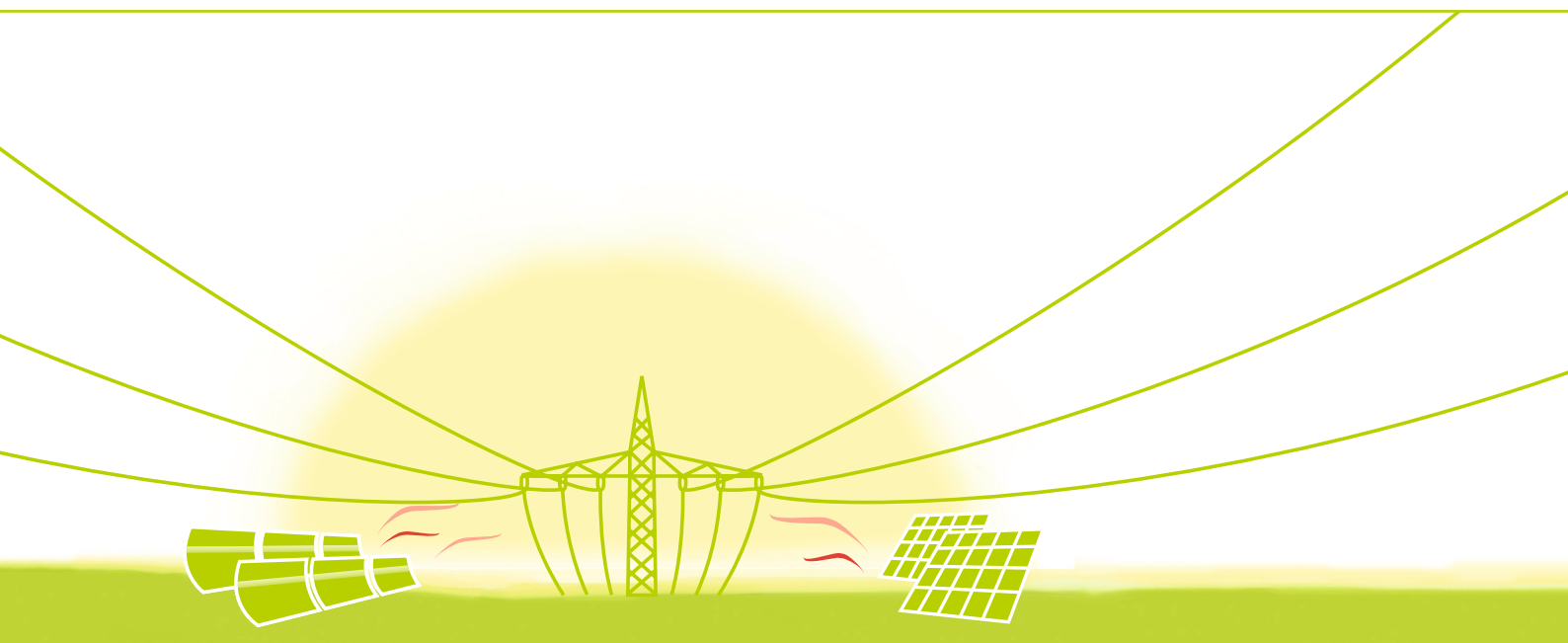
Giga Sponsor:



Mega Sponsor:



Organizer:



# PROCEEDINGS

Edited by Uta Betancourt / Thomas Ackermann

## 6<sup>th</sup> Solar Integration Workshop

International Workshop on Integration  
of Solar Power into Power Systems



14 - 15 November 2016 | Vienna, Austria

Giga Sponsor:



Mega Sponsor:



Supported by:



Media Partners:



Organizer:



## **IMPRINT**

Proceedings  
of the 6th International Workshop on Integration of Solar Power into Power Systems  
published in 2016 by:

**Energynautics** GmbH  
Robert-Bosch-Straße 7  
64293 Darmstadt  
Germany  
[www.energynautics.com](http://www.energynautics.com)  
[info@energynautics.com](mailto:info@energynautics.com)

All rights reserved. No part of this publication may be reproduced, transmitted or stored  
in a retrieval system in any form or by any means without permission in writing  
from the respective author.

ISBN: 978-3-9816549-3-6

Cover Design by:  
Ines Drewianka, **Energynautics** GmbH, Germany

Printed by:  
Kopierart GbR, Berlin, Germany  
[www.kopierart.de](http://www.kopierart.de)

# Table of Contents

## Session 1 – Keynote Session: 1

09:00 – 10:50 / 14 November 2016 / Room Grand Waterfront 1+2+3 / Session chair: T. Ackermann (Energynautics, Germany)

### **The Speed of PV Development World-Wide - A New Dimension for Power Systems**

T. Ackermann (Energynautics, Germany)

### **The Impact of Renewables and Strategies for Integration in Wiener Netze Distribution Grid**

T. Schuster (Wiener Netze, Austria)

### **Optimization of the Balancing Market in Austria**

Ch. Todem (APG, Austria)

### **Communication in the Tension Between Renewables and Power Grid Development**

F. Wöber (APG, Austria)

## Session 2A: Grid Integration Studies and Experience 3

11:15 – 13:00 / 14 November 2016 / Room Grand Waterfront 1 / Session chair: J. C. Smith (UVIG, USA)

### **The Eastern Renewable Generation Integration Study: Insights on System Stress**

A. Bloom, J. Novacheck (NREL, USA)

### **Linking Technical Grid Integration Studies with Long Term Techno-Economic Planning Studies for Isolated Power Grids**

E. Taibi, F. Gafaro, P. Journeay-Kaler, I. Portugal (International Renewable Energy Agency [IRENA], Germany), J. Gómez, F. Fernandez (DlG SILENT, Germany)

### **Demonstration of Active Power Controls by Utility-Scale PV Power Plant in an Island Grid**

V. Gevorgian, B. O'Neill (NREL, USA)

### **Maximizing the Penetration of Inverter-Based Generation on Large Transmission Systems: the MIGRATE Project**

M.-S. Debry, G. Denis, T. Prevost, F. Xavier (RTE, France), A. Menze (TenneT Offshore, Germany)

## Session 2B: PV and Smart Grid Concepts 31

11:15 – 13:00 / 14 November 2016 / Room Grand Waterfront 2 / Session chair: B. Engel (TU Braunschweig, Germany)

### **Capacity Management of Low Voltage Grids Under the Energy Transition**

E. J. Coster, M. Broekmans, J. P. Hodemaekers, H. A. Fidler (Stedin, Netherlands)

### **Decentralized Battery Energy Storage System – Application and impact in a Distribution System with Cloud Connection**

A. Berthold, M. Hausladen (ABB, Germany), D. Speiser (EWE NETZ, Germany)

### **Automatic Integration of Photovoltaic Inverters in a Smart Grid System to establish Additional Power Grid Beneficial Functions**

P. Steinbusch, R. Uhlig, S. Fischer, M. Stötzel, M. Zdrallek (University of Wuppertal, Germany), T. Bülo (SMA Solar Technology, Germany), W. Friedrich, U. Schlüter (Mauell, Germany)

### **Modular PLC-Based Control Concepts for Integration of PV Plants to Power Distribution Grids**

T. Oesselke (Phoenix Contact Electronics, Germany)

11:15 – 13:00 / 14 November 2016 / Room Grand Waterfront 3 / Session chair: C. Mayr  
(AIT Austrian Institute of Technology, Austria)

**Survey and Case Studies of Transmission Level PV Integration Assessments Utilizing Generation Forecasts and Innovative Flexibility Resources**

K. Ogimoto (University of Tokyo, Japan), A. Marinopoulos (ABB, Sweden), K. Clark, B. Mather (NREL, USA), K. Asano, K. Ohbayashi (NEDO, Japan), K. Frederiksen (Kenergy, Denmark), I. McGill (University of New South Wales, Australia), A. Iaria (RSE, Italy), M. Kraicz (Fraunhofer IWES, Germany), P. Vingerhoets (KU Leuven, Belgium), C. Mayr, R. Bründlinger (AIT – Austrian Institute of Technology, Austria)

**A Comprehensive Study on the Actual Potential of Grid Support Functions to Enhance the Hosting Capacity of Distribution Networks with a High PV Penetration**

S.Kadam, B. Bletterie (AIT, Austria)

**Review and Assessment of Latest Grid Code Developments in Europe and Selected International Markets with Respect to High Penetration PV**

R. Bründlinger (AIT, Austria)

**Automated Grid Planning for Distribution Grids with Increasing PV Penetration**

A. Scheidler, M. Kraicz (Fraunhofer IWES, Germany), L. Thurner (University of Kassel, Germany), M. Braun (Fraunhofer IWES | University of Kassel, Germany)

**Progress and Future of Japan's PV Deployment**

K. Ogimoto (University of Tokyo, Japan), K. Ohbayashi, K. Asano (NEDO, Japan)

**Managing Integration of Distributed PV in North America**

T. Key (EPRI, USA)

Session 3A: PV and Storage in Distribution Systems

105

14:00 – 15:45 / 14 November 2016 / Room Grand Waterfront 1 / Session chair: T. Key (EPRI, USA)

**Testing and Validation of Simultaneous Multiple Use of Photovoltaic Storage Systems**

F. Lobas-Funck, F. Soyck, B. Engel (Technical University Braunschweig, Germany)

**Preventing Overvoltage in a Distribution Grid with Large Penetration of Photovoltaic Power**

R. Luthander, D. Lingfors, J. Widén (Uppsala University, Sweden)

**System Supporting Storage Deployment for the Compensation of Grid Effects Caused by PV in a Distribution Grid**

T. Nacht, M. Tragner (4ward Energy Research, Austria)

**Dynamic Battery Storage Models for Investigation of Dynamic Voltage Stabilization**

W. Shan, M. Shan (Fraunhofer IWES, Germany)

Session 3B: System Study Modelling

135

14:00 – 15:45 / 14 November 2016 / Room Grand Waterfront 2 / Session chair: Julija Matevosjana  
(ERCOT, USA)

**Determination of WECC Distributed PV System Model Parameters for Partial Loss of Generation Due to Bulk System Voltage Sags**

J. C. Boemer, E. Vittal, M. Rylander (EPRI, USA), B. Mather (NREL, USA)

**Characterization of Harmonic Emission of Individual Wind Turbines and PV inverters based on measurements – Part I – Photovoltaic Inverters**

F. Ackermann, H. Moghadam (Fraunhofer-ISE, Germany), J. Meyer, S. Mueller, M. Domagk (Technical University Dresden, Germany), F. Santjer (UL International/DEWI, Germany), I. Athamna (FGW – Federation of German Windpower and other Renewable Energies, Germany), R. Klosse, K. KÜch (WindGuard Certification, Germany)

**A Novel Control Algorithm for Grid-Connected Inverters improving Power Quality using Voltage Control and Virtual Impedance**

S. Reichert, B. Stickan (Fraunhofer ISE, Germany)

**Power System Model Reduction with Grid-Connected Photovoltaic Systems Based on Hankel Norm Approximation**

I. Maqbool (Fraunhofer IWES, Germany), G. Lammert (University of Kassel, Germany), A. Ishchenko, (Phase to Phase BV, Netherlands), M. Braun (Fraunhofer IWES | University of Kassel, Germany)

**A Transient Stability Improvement by Decentralized Non-Linear Control of Active and Reactive Power of PV**

K. Furubayashi, T. Tsuji, T. Oyama (Yokohama National University, Japan), K. Uchida (Waseda University, Japan)

---

14:00 – 15:45 / 14 November 2016 / Room Grand Waterfront 3 / Session chair: D. Lew (GE, USA)

**Methods to Ensure Deliverability of System Flexibility**

E. Ela, E. Lannoye, A. Tuohy (EPRI, USA)

**Synthetic Natural Gas Production and Utilization in the North European Power System in 2050**

J. Ikäheimo, J. Kiviluoma (VTT, Finland)

**A Study on Power System Reliability Evaluation with Massive Penetration of Solar Power Generations**

S. Yamashita, T. Tsuji, T. Oyama (Yokohama National University, Japan), Y. Nakachi, S. C. Verma (Chubu Electric Power, Japan)

**Hybrid Industrial Power systems Mixing Photovoltaic & Diesel Power Generation: Optimizing PV Penetration Rate and Securing Stability**

D. Goulielmakis, G. Scaringella, J. Philippe (Schneider Electric, France)

---

Session 4A: Frequency and Reserve Issues

16:00 – 18:15 / 14 November 2016 / Room Grand Waterfront 1 / Session chair: E. Tröster

(Energynautics, Germany)

**Frequency Control in Distributed Inverter-Dominated Electrical Power Systems**

S. Laudahn, J. Seidel, B. Engel (Technical University Braunschweig, Germany), T. Bülo, D. Premm (SMA Solar Technology, Germany)

**Primary Operating Reserves from Concentrated Solar Power Plants (CSP)**

S. Ott (University of Applied Forest Sciences Rottenburg, Germany), P. Lilje (M.P.E., Germany), M. Brunotte (University of Applied Forest Sciences Rottenburg, Germany)

**A Study on Influence of Ramp Event of Aggregated Power Output of Photovoltaic Power Generation on Electric Power System Frequency**

T. Kato, Y. Manabe, T. Funabashi, M. Kurimoto (Nagoya University, Japan)

**Modelling of Small-Scale Photovoltaic Systems with Active and Reactive Power Control for Dynamic Studies**

D. Fetzer, G. Lammert, K. Fischbach, M. Nuhn, J. Weide, D. Lafferte, T. Paschedag (University of Kassel, Germany), M. Braun (Fraunhofer IWES, Germany)

**Integration of PV-Units in the Tertiary Control Ancillary Services Market in Switzerland**

A. Chacko (Swissgrid, Switzerland), V. Wyss, M. Koller, S. Poelzig (Electricity company of canton Zurich (EKZ), Switzerland), F. Carigiet, F. Baumgartner (Zurich University of Applied Science (ZHAW), Switzerland)

---

Session 4B: Economics and Storage

16:00 – 18:15 / 14 November 2016 / Room Grand Waterfront 2 / Session chair: P. Gardner

(DNV GL - Energy, United Kingdom)

**Energy Storage: Is There a Business Case?**

D. Lew (GE Energy, USA)

**Through the Valley: The Impact of PV Penetration Levels on Price Volatility and Resulting Revenues for Storage Plants**

M. Hartner (Vienna University of Technology, Austria)

**Quantifying the Storage Requirements Needed To Achieve High PV Penetration in the U.S.**

P. Denholm, R. Margolis (NREL, USA)

**Merit Order Effect of Flexibility Options**

M. Hinterstocker, B. Eberl, S. von Roon (Forschungsgesellschaft für Energiewirtschaft, Germany)

**PV Generation Share in the Energy System and Battery Utilisation Correlation in a Net Zero Emission World**

D. Bogdanov, A. Gulagi, C. Breyer (Lappeenranta University of Technology, Finland)

---

16:00 – 18:15 / 14 November 2016 / Room Grand Waterfront 2 / Session chair: T.B.A.

**Stability Assessment for Automated Voltage Controlling Equipment in Distribution Grids**

M. Schoeneberger, S. Patzack, H. Vennegeerts (FGH / RWTH Aachen University, Germany)  
(Submission-ID SIW16-162)

**Spatio-temporal Analysis of Regional PV Generation**

E. Nuño, N. Cutululis (DTU, Denmark)

**Identification and Reconstruction of Photovoltaic Measurement Gaps based on Temporal Correlation and Spatial Distance**

P. Zehetbauer, S. Kloibhofer, M. Stifter, B.-V. Mysore-Vasudevarao, F. Leimgruber (AIT - Austrian Institute of Technology, Austria)

**Advancing Distribution Planning Tools for DER Impact Assessments: Streamlining DER Hosting Capacity Analysis**

M. Rylander, J. Smith (EPRI, USA)

**Optimised Control of 10 MW Photovoltaic (PV) Plant with 1MW / 1MWh Battery**

P. Nørgaard, H. Bindner, A. Thavlov (DTU, Denmark), M. Florides, V. Venizelou, M. Patsalides, C. Anastassiou, G. Makrides, V. Efthymiou, G. E. Georghiou, (University of Cyprus, Cyprus)

**Study on Optimization Methods for Active Distribution Network with a Large Penetration of PV**

Y. Shiratori, T. Tsuji, T. Oyama (Yokohama National University, Japan), Y. Nishida (Tokyo Electric Power Company Holdings, Japan)

---

08:15 – 09:55 / 15 November 2016 / Room Grand Waterfront 1 / Session chair: T. Ackermann  
(Energynautics, Germany)

**Scaling up Variable Renewable Power: The Role of Grid Codes**

Francisco Boshell (IRENA, Germany)

**The Role of Grid Codes for VRE Integration into Power Systems**

P. Schierhorn, N. Martensen, T. Ackermann (Energynautics, Germany)

**Status of Revision of the VDE-AR-N 4105 Application Guide for the Connection of Distributed Generation to Low Voltage Networks**

J. Suckow (VDE/FNN, Germany), J. C. Boemer (EPRI, USA)

**State of the National Implementation of the NC RfG in Germany**

J. Möller, K. Genzmer (M.O.E. Moeller Operating Engineering, Germany)

**Status of Revision of IEEE Std 1547 and 1547.1**

J. C. Boemer, A. Huque, B. Seal, T. Key, D. Brooks (EPRI, USA), C. Vartanian (Mitsubishi Electric Power Products, USA)

---

08:15 – 09:55 / 15 November 2016 / Room Grand Waterfront 2 / Session chair: TBA

**Solar Irradiance Forecasting Using Satellite Data in Reunion Island: a Comparison Between Cloud Pattern Extrapolation and Autoregressive Algorithms**

S. Cros, M. Turpin, M. De Roubaix, N. Schmutz (Reuniwatt, France)

**Validation of Solar Irradiance Forecasts Using High-Resolution Numerical Prediction Models**

H. Ohtake, F. Uno (National Institute of Advanced Industrial Science and Technology (AIST), Y. Yamada (Meteorological Research Institute of the Japan Meteorological Agency, Japan)

**Development of Solar Forecasting in India: The Introduction of REMCs**

M. Kaur, I. Mitra, M. Wypior, S. Kumar Sharma, A. Ramanan (GIZ, India)

**A Combined Pyramidal Image Matcher and Analog Ensemble Method to Improve Satellite-Based Short-Term Solar Power Prediction in the Hawaiian Islands**

S. Young, J. Zack (AWS Truepower, USA)

**Short-Term PV Power Prediction Analysis of Different Latitudes in the Condition of PV Power Curtailment**

Y. Cui, Z. Chen, P. Sun (Hubei Meteorological Service Center | Meteorological Energy Development Center of Hubei Province, Wuhan, China)

---

08:30 – 09:55 / 15 November 2016 / Room Grand Waterfront 3 / Session chair: TBA

**Solving the Community Storage Dilemma – Higher Utilization by Multiple Usage**

C. Stegner, A. Blockinger, J. Bogenrieder, P. Luchscheider (ZAE Bayern, Germany)

**Limitations of Integrating Photovoltaic Energy into Municipal Grids Excluding and Including Storage Systems**

B. Böckl, J. Vopava, L. Kriechbaum, T. Kienberger (Montanuniversitaet Leoben, Austria)

**Field Assessment of PV-Home Storage Systems**

C. Messner, J. Kathan, C. Seidl, S. Hofmüller (AIT – Austrian Institute of Technology, Austria), J. Wolfahrt (Fronius International, Austria)

**Integration of Storage into a Renewables Portfolio to Optimise Revenue & Grid Connection Utilisation**

S. Weatherhead, G. McFadzean, C. Cleary, L. Russell (TNEI Services, United Kingdom)

---

10:10 – 11:15 / 15 November 2016 / Room Grand Waterfront 1 / Session chair: R. Bründlinger  
(AIT – Austrian Institute of Technology, Austria)

**The Barbados Grid Code as a Template for a Caribbean Grid Code – Following the Ideas of the ENTSO-E Grid Codes**

N. Martensen, T. Ackermann (Energynautics, Germany)

**New Zealand Guideline for the Connection of PV Solar Power and Determining Hosting Capacity for PV Solar Power**

R. Strahan, S. McNab, S. Pandey, S. Lemon, A. Miller, N. Watson, A. Wood (University of Canterbury, New Zealand), T. Crownshaw (Transpower NZ, New Zealand)

**Building a Level Playing Field for Distributed Solar Photovoltaic in Australia**

S. Teske, J. Rutovitz, L. McIntosh (University of Technology Sydney, Australia)

---

10:10 – 11:15 / 15 November 2016 / Room Grand Waterfront 3 / Session chair: TBA

**Merit Order of Grid Optimizing Measures for a Sustainable Grid Planning and Efficient Solar Integration**

S. Köppl, A. Zeiselmaier, A. Bogensperger, M. Müller, M. Hinterstocker, F. Samweber (FfE – Research Center for Energy Economics, Germany)

**Policies of PV Self-Consumption: Disruptive Potential on Balancing Systems**

M. Döring, M. Bons, S. Tiedemann (Ecofys Germany, Germany)

**Constructing Offering Curves for a CSP Producer in Day-ahead Electricity Markets**

I. Dimoulkas, D. Khastieva, M. Amelin (KTH Royal Institute of Technology, Sweden)

---

11:30 – 12:15 / 15 November 2016 / Room Grand Waterfront 1+2+3 / Session chair: TBA

**Podium discussions**

**The contributions and discussions of this session are not part of the proceedings.**



**Symbiotic Operation of Large PV and Wind Power Plants**

R. Grab, F. Ackermann, S. Rogalla (Fraunhofer ISE, Germany)

**Techno-economic Optimum Control of Grid-connected Residential Battery Energy Storage Units**

I. Ranaweera, O.-M. Midtgård (Norwegian University of Science and Technology, Norway)

**East Asian Super Grid: Can Australia Become an Electricity Source for Asia?**

A. Gulagi, D. Bogdanov, C. Breyer (Lappeenranta University of Technology, Finland)

**Feeder Analyses of a Medium Voltage Grid with the Utilization of a Solar-Roof-Potential-Analyses**

F. Ebe, J. Morris, H. Ruf, G. Heilscher (Ulm University of Applied Sciences, Germany), F. Meier (Stadtwerke Ulm/Neu-Ulm Netze, Germany)

**Optimal Scheduling of Plug-in Electric Vehicles in Distribution Systems Including PV, Wind and Hydropower Generation**

S. Zaferanlouei, I. Ranaweera, M. Korpås, H. Farahmand (Norwegian University of Science and Technology, Norway)

**Copula Correlation Modeling of Aggregate Solar Irradiance in Spatial Networks**

J. Munkhammar, J. Widén (Uppsala University, Sweden)

**The Impact of Large-Scale Renewable Energy Integration on the Utilization of Pumped Hydro Storage in Spain**

E. Rye, A. Lie, H. G. Svendsen (SINTEF Energy Research, Norway), M. Korpås, H. Farahmand (Norwegian University of Science and Technology, Norway)

**Case Studies Analysis of Renewable Energy Implementation into the Mining Industry**

K. Zharan, J. Bongaerts (TU Bergakademie Freiberg, Germany)

**A Transient Stability Assessment Method of Power Systems by using Dynamical Systems Theory in Japanese 60Hz Power System with Photovoltaics**

A. Hatano, T. Tsuji, T. Oyama (Yokohama National University, Japan)

**Assessment of Probabilistic PV Production Forecasts Performance in an Operational Context**

A. Bocquet, A. Michiorri, A. Bossavy, R. Girard, G. Kariniotakis (MINES ParisTech, France)

**Development of a RDS-PP Guideline for Photovoltaic Power Plants**

C. Bertsch-Engel (CEE Operations, Germany), A. Böser (VGB PowerTech, Germany)

**Experimental Research on the Optimal Tilted Angle for PV Modules in Wuhan, China**

Z. Chen, P. Sun, C. Cheng (Hubei Meteorological Service Center | Meteorological Energy Development Center of Hubei Province, China), G.-G Yan (Wuhan Rixin Technology, China)

**Application and Effect Test of A Method of Gradually Approaching Error for the Solar Radiation Prediction**

Z. Chen, P. Sun, (Hubei Meteorological Service Center | Meteorological Energy Development Center of Hubei Province, China), R. Zhang (Hubei Provincial Meteorological Administration Training Center, China)