

# PROCEEDINGS

1<sup>st</sup> International Workshop on

# Integration of Solar Power into Power Systems



24 October, 2011, Aarhus, Denmark

Organized by  
Energynautics GmbH  
(Germany)



Goldsponsor:





# PROCEEDINGS

## 1<sup>st</sup> International Workshop on Integration of Solar Power into Power Systems

24 October, 2011  
Aarhus, Denmark

Edited by Uta Betancourt / Thomas Ackermann

Sponsored by:



## **Imprint**

Proceedings  
of the 1st International Workshop on Integration of Solar Power into Power Systems  
published in 2011 by

Energynautics GmbH  
Mühlstraße 51  
63225 Langen  
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 978-3-98 13870-4-9

Cover design by:  
Sabine Leskien, Berlin, Germany

Printed by  
Kopierart GbR, Berlin, Germany  
<http://kopierart.de>

# Welcome to the 1<sup>st</sup> International Workshop on Integration of Solar Power into Power Systems

It is a great pleasure to welcome you to the 1<sup>st</sup> edition of the *International Workshop on Integration of Solar Power into Power Systems* in Aarhus, Denmark.

The initial idea for a Solar Integration Workshop was already born a few years ago, but interest was rather low. But at the Wind Integration Workshop in Québec City, Canada in 2010, more and more participants indicated their interest in Solar Integration Issues, so we thought it is time to launch the idea again. This time, the feedback was much better than we anticipated, with close to 100 abstracts submitted following the call for papers which allowed us to compile a very interesting program.

Similar to the wind integration workshop, the general purpose of this workshop is to bring together utilities, PV/CSP system developers and project developers, power systems operators and other professionals to exchange knowledge and ideas, as well as experiences in matters relating to the integration of solar energy into the power systems.

The aim of the first workshop is to provide a full overview of all relevant topics related to Solar Integration with special focus on the German integration experiences. We hope that this 1<sup>st</sup> *International Workshop on Integration of Solar Power into Power Systems* is the beginning of a long, interesting success story, with many interesting presentations and discussions.

I like to mention that the 1<sup>st</sup> *Solar Integration Workshop* is part of a whole Renewable Energy Week this year in Aarhus, Denmark, with a number of related events such as *Tutorials for the Solar Integration Workshop* (October 23, 2011) and *Tutorials on Wind Turbine Modeling* (October 24, 2011), the 10<sup>th</sup> *International Workshop on Large-Scale Integration of Wind Power into Power Systems as well as on Transmission Networks for Offshore Wind Power Plants* (October 25-26, 2011), the *Fifth Workshop on Best Practice in the Use of Short-term Forecasting of Wind Power* (October 24th, 2011), the dedicated TSO-*Energinet.dk-day* (October 27, 2011) and two different *field trips* (October 27 and 28, 2011).

In order to make the contributions to this workshop easier available for academia and industry worldwide we will submit the proceedings to international libraries and organisations who operate citation index systems such as the (i) FIZ - Fach Informations Zentrum Karlsruhe, (ii) Elsevier, (iii) ETDE, (iv) Reuters, (v) Compendex, (vi) ThomsonCitationIndex.

This workshop would not be possible without the support of our Gigasponsor **Danfoss**. Above all, we would like to thank the Danish TSO **Energinet.dk** for its general support and local assistance.

We would also like to thank all those who supported the organizers of this workshop: Uta Betancourt and Jörg Braun (all Energynautics, Germany), Antje Orths (Energinet.dk) and the International Advisory Committee.

Have an inspiring stay in Aarhus and a fruitful workshop!

Thomas Ackermann  
*energynautics*

# Table of Contents

## Session 1: Keynote Session

1

---

09:00 – 11:00 / 24 October 2011 / Room Suecia / Discussion leader: Thomas Ackermann,  
(Energynautics, Germany)

**Overview of German Grid Issues and Retrofit of Photovoltaic Power Plants in Germany for the Prevention of Frequency Stability Problems in Abnormal System Conditions of the ENTSO-E Region Continental Europe**

J. C. Boemer, K. Burges (Ecofys Germany, Germany), P. Zolotarev, J. Lehner (University of Stuttgart, Germany), P. Wajant, M. Fürst (EnBW, Germany), R. Brohm (BSW-Solar, Germany), T. Kumm (VDE FNN, Germany)

**Operational Impact of High Solar Penetrations in the Western U.S.**

N. Miller (GE Energy, USA), K. Clark (NREL), G. Jordan (Consultant to GE Energy, USA), Z. Gao (GE Energy, USA), D. Lew (NREL)

**Characterisation and Integration of High Penetration Solar Power in Australia - A Solar Intermittency Study**

S. Sayeef, T. Moore, S. Percy, D. Cornforth, J. Ward, D. Rowe (CSIRO, Australia)

**Photovoltaic Energy: Methods Developed by RTE to Facilitate Integration of this Production**

E. Neau (RTE, France)

## Session 2a: Modeling and Integration Issues

33

---

11:30 – 13:00 / 24 October 2011 / Room Suecia / Discussion leader: T.B.A.

**Considerations on the Modeling of Photovoltaic Systems for Grid Impact Studies**

V. Čuk, P. F. Ribeiro, J. F. G. Cobben, W. Kling (TU Eindhoven, the Netherlands),  
F. R. Isleifsson, H. W. Bindner (Risø DTU, Denmark), N. Martensen (Energynautics, Germany), A. Samadi, L. Söder (KTH, Sweden)

**Wind Power Integration Case Compared to Solar Power Integration**

B. Vet, G. Dekker, P. Raats, E. De Jong (KEMA, the Netherlands)

**Voltage Stability Issues in a Distribution Grid with Large Scale PV Plant**

A. R. Pérez, A. Marinopoulos, M. Reza, K. Srivastava (ABB Corporate Research, Sweden),  
D. Van Hertem (KULeuven, Belgium)

**Calculation of Harmonic Current Content in PV Power Plants Based on Single Inverter Data**

A. Constantin, R. D. Lazar, J. Dannehl, S. B. Kjær (Danfoss Solar Inverters, Denmark), M. Ibsch (GL Garrad Hassan, USA)

---

11:30 – 13:00 / 24 October 2011 / Room Dania / Discussion leader: T.B.A.

**Solar Power Forecasting Performance – Towards Industry Standards**

V. Kostylev, A. Pavlovski (Green Power Labs, Canada)

**Weather Class Depending Combinations of Solar Power Forecasts – Operational Experiences**

J. Schmelter, M. Lange, U. Focken (energy & meteo systems, Germany)

**Forecasting DNI and GHI Based on the WRF Model: An Evaluation Study in Andalusia (Southern Spain)**

V. Lara Fanego, J. Ruiz Arias, A. D. Pozo Vázquez, F. J. Santos Alamillos, J. Tovar Pescador, S. Quesada Ruiz (University of Jaén, Spain)

**Solar Ramping Distributions over Multiple Timescales and Weather Patterns**

B.-M. Hodge, M. Hummon, K. Orwig (NREL, USA)

---

14:00 – 15:40 / 24 October 2011 / Room Suecia / Discussion leader: T.B.A.

**Integration of Photovoltaic Systems with Voltage Control Capabilities into LV Networks**

B. Blažič, I. Papič, B. Uljanić (University of Ljubljana, Slovenia), B. Bletterie (Austrian Institute of Technology, Austria), C. Dierckxsens, K. De Brabandere (3E, Belgium), W. Deprez (Infrac, Belgium), T. Fawzy (SMA Solar Technology, Germany)

**Estimation of Maximum Allowable PV Power Connection to Low Voltage Residential Networks: A Case Study of Braedstrup**

E. Demirok, D. Sera, R. Teodorescu (Aalborg University, Denmark)

**Smooth Integration of CSP Plants in Power Systems**

J. Usaola (University Carlos III Madrid, Spain)

**Molten Salt Concentrating Solar Plants: their Potential Contribute to a Better Grid Integration of Solar Power**

M. Falchetta (ENEA, Italy)

---

14:00 – 15:40 / 24 October 2011 / Room Dania / Discussion leader: T.B.A.

**Electrical Characteristics of Solar Systems**

F. Santjer (DEWI, Germany)

**Disadvantages of Non-optimal Implementations of Power Reduction during Over-frequency Events**

M. Wilch (TÜV NORD CERT, Germany)

**The Long-term Effects of High Shares of PV in the Power System – An Analysis of the German Power Market**

M. Nicolosi, C. Nabe (Ecofys, Germany)

**Aspects of a Generic Photovoltaic Model examined under the German Grid Code for Medium Voltage**

I. T. Theologitis, E. Tröster, T. Ackermann (Energynautics, Germany)

---

16:00 – 17:30 / 24 October 2011 / Room Suecia / Discussion leader: T.B.A.

**Impacts of Electricity Markets on Solar Revenues - An Australian Case Study**

J. Riesz, J. Gilmore, M. Buchanan, B. Vanderwaal, I. Rose (ROAM Consulting, Australia)

**Smart Integration of Photovoltaic Power Systems on the Island of Bornholm**

G. Yang, J. Østergaard, S. B. Kjær, A. Constantin, H. P. Ballegaard, R. D. Lazar, U. Borup, C. Stephansen, M. Mattesen, J. B. Sørensen (DTU, Denmark)

**Modelling and Statistical Analysis of the Variability of Large-Scale Solar Power in High-Latitude Power Systems**

J. Widén (Uppsala University, Sweden)

**Urban Solar Electricity Schemes with High Solar Fraction – Strategies for Integration and Managing Energy System**

P. D. Lund, R. Niemi, J. Mikkola, J. Lindgren (Aalto University, Finland)

---

17:30 – 18:30 / 24 October 2011 / Room Suecia / Discussion leader: TBA

**Solution to Avoid Unwanted Trips for PV Systems Connected to LV Network Facing Voltage Sags**

C. Le-Thi-Minh, T. Tran-Quoc (IDEA, France), S. Bacha (Grenoble Electrical Engineering Laboratory, France), C. Kieny (IDEA, France), P. Cabanac, S. Grenard (EDF, France), D. Goulielmakis (Schneider Electric, France)

**Analysis of the Effects of Demand Response to the Integration of Renewable Energy into the Distribution Grid**

O. Warweg, A. Arnoldt, C. Troitzsch, S. Frenzel, M. Werner, P. Bretschneider (Fraunhofer IOSB-AST, Germany)

**Solar Plant Integration and Analysis of Effect in the MV Electricity Grid**

M. Katsanevakis, E. Demirok, D. Sera (Aalborg University, Denmark)

**Capability to Provide Reactive Power in PV Farms: Implementation of LV Capacitors**

I. Gal, M. Q. Nguyen (Schneider Electric, France)

**Stability Analysis of Isolated Grid Incorporated With Large-scale Photovoltaic Power**

G. He, K. Feng, G. Li, W. Bao, W. Shi, W. Zhao (CEPRI, China)

**Solar Data Inputs for Integration and Transmission Planning Studies**

K. Orwig, M. Hummon, B.-M. Hodge, D. Lew (NREL, USA)

**Management of Photovoltaic Power Generation with a Vanadium RedOx Flow Energy Storage System**

F. Bourry, P. Besson (INES-CEA L2S, France), N. Martin (INES-CEA LSE, France), X. Le Pivert (INES-CEA L2S, France), M. Perrin (INES-CEA LSE, France)

**Online Short-term Solar Power Forecasting**

P. Bacher, H. Madsen (DTU, Denmark), H. A. Nielsen (ENFOR, Denmark)

**Evaluating Impact of Solar Generation on Balancing Requirements in Southern Nevada System**

J. Ma, S. Lu, P. V. Etingov, N. A. Samaan, R. P. Hafen, Y. V. Makarov (PNNL, USA), V. Chadliev (NV Energy, USA)

**Analysis on the Impacts of Solar PV Energy Electric Generation Residential Applications to Low Voltage Grid by a Monte-Carlo Simulation**

W. Du (TU Delft, the Netherlands)

Workshop Participants 229

---

Workshop Information 233

---