

iPLON meeting Chennai – Solar Cluster

September 29th 2017, Chennai, India

Current research topics

Grid integration of renewable energy sources – Evaluation of PV Power Plants – Wind/Solar power forecasting

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Stuttgart:

Photovoltaics (with Solab), Energy Policy and Energy Carriers, Central Division Finance, Human Resources and Legal



Widderstall: Solar Test Facility

ZSW Locations

Stuttgart Widderstah bei Merkingen



Ulm: Electrochemical Energy Technologies, Main Building & eLaB



- 1 -

Center for Solar- and Hydrogen Research Baden-Wuerttemberg (ZSW)

ZSW is a non-profit foundation with 230 employees and a turnover of ca. 35 m.€ (2016).

The focus is on • Systems Analysis and Consulting

- Photovoltaics : System Technology & Material Research
- Renewable Fuels and Reformers
- Fuel Cells and Hydrogen Technology
- Electrochemical Storage

From materials research to systems applications and production.





Research in Photovoltaics: from Materials (thin film CIGS) to System Application and Testing



Photovoltaics: System Technology

- Module technology
- System measurements
- Yield estimates and site appraisals / consulting
- Customer-specific indoor and outdoor testing
- Solar testing facility in Widderstall/Germany
- Grid integration of PV plants with energy storage and self-consumption









GRID INTEGRATION OF RENEWABLE ENERGY SOURCES

Part I

Cost of "Energiewende" in Germany in a scenario of 1000 TWh from RES in 2050



Turning point expected in 2030 ... 2035:

when savings on import =

yearly invest for new installations of RES + investment to save energy

Year > 2035: Energy System based on RES provides lower cost and reduces dependancy on imports



Profile of electricity generated from RES 2 sample weeks in year 2050 for >60% RES scenario



- use surplus electricity from Wind and PV
 - for electromobility
 - to charge thermal storage
 - for power-to-gas



* Norman Gerhard, (Fraunhofer IWES), INTERAKTION EE-STROM, WÄRME UND VERKEHR", Endbericht, Sept. 2015,

Generation, Storage and Distribution Coupling of the 3 Energy Sectors allows for Load Management to match up Generation and Load



Use surplus of electricity for Heat and Mobility



- (1) use surplus of electricity for existing high temperature heating systems
- (2) Increase deployment of RES
- (3) continue deployment of heat pump for low temperatur heat
- (7) increased use of electricity from RES at generation peaks for high temperature heat

* Adopted from Norman Gerhard, (Fraunhofer IWES et.al.), INTERAKTION EE-STROM, WÄRME UND VERKEHR", Endbericht, Sept. 2015,



- 10 -

PV Storage Systems and Grid Integration of PV



- Design of PV battery systems
- Characterisation of battery operation and ageing
- Energy management, optimisation of self-consumption
- Strategies to minimize grid loading
- Smart grids on distribution network level



- -- Injection power limit
- PV power [W]
- consumption [W]
- Injected power [W]
- SOC battery [Wh]





Grid Integration of PV by Model Predictive Local (Storage) Control

Goals of the Optimization

- Maximization of own-consumption of locally produced PV energy
- · Compliance with feed-in limits into the grid

Model predictive local control: Calculation of optimized profiles for charging power and load power from forecasts of irradiance, electrical and thermal loads



Model Predictive Control operating principle

2. Optimization

- Calculate the optimized trajectory to achieve goals
- Objectives: minimizing energy costs

- comply with grid limits



Curtailed Energy and Self Consumption (Feed In Limit: 30% PVpeak)

Comparison of curtailed energy and self consumption levels





Storage and Load Management within the Distribution Network (Virtual Power Plants)



- ZSW: Development and comparison of storage and load management schemes that are optimized with respect to interests of the supplier of electricity, grid operator and/or customer
 - implementation of such schemes through selection of HW and development of SW for control and communication at customer premises





EVALUATION OF PV POWER PLANTS

Part II

Failure modes of PV modules





PID

Hot bypass diodes

Soiling

TCO-Delamination EVA-Browning

How can we provide accelerated lab tests to avoid reliability issues in the field??



ZSW Photovoltaics Test Laboratory Solab

- Stress tests according to IEC 61215, 61646, 61730 and beyond
- STC and low-light power measurements
- Potential-induced degradation (PID), IEC 62804
- Mechanical load, electroluminescence, thermography
- Bankability and quality tests
- c-Si and thin film









ZSW Consulting for Manufacturers, Investors, Project Developers, Research Partners

- Technical due diligence
- PV System measurements and acceptance tests
- PV module factory inspection







Evaluation and benchmarking of PV Power Plants

- Final Yield Yf:
 - Yf = Eo / Po
 - Eo energy yield delivered to grid (MWh per day or year)
 - Po rated power of PV plant (MW)
- Reference Yield Yr:
 Yr = Hi / G_{STC}
 - Hi irradiation on PV array (kWh/m² per day or year)
 - G_{STC} reference irradiance (1 kW/m²)
- Performance Ratio PR: PR = Yf / Yr (PR is dimension less)
 - PR depends on module temperature, technology, site



Performance Ratio PR for PV systems in Germany)*



Performance Ratio target: 85% and beyond

)*Source: International Energy Agency IEA Report IEA-PVPS T13-03:2014



ZSW Services for O&M of PV plants



- Performance assessment based
 on operational data
- Identification of deviations on string/inverter level
- Field inspection and failure analysis
- Training and workshops

Inspection of 50MW PV in Quinghai/China by ZSW





Part III

PV/WIND POWER FORECASTING & OPTIMISATION OF POWER PLANTS



Photovoltaics and wind power forecasts



// Wind/Solar Power Forecasting



25W

The P²IONEER model:

Simulation and optimization of hybrid power plants





P²**IONEER optimization** goals

Optimal Energy Mix



Levelized Costs Of Electricity in €ct/kWh

10

7

4

1

-2

Measure-Correlate-Predict (MCP): Benchmarking wind power long-term yield prediction







- Energy systems based on RES offer many benefits
- Grid integration of PV plants with sector coupling, self-consumption, energy storage & smart energy management

 Do you know the performance of your solar park?
 ZSW Services for O&M of PV plants





 Do you know the yield of your PV plant for the next 60 hours?
 ZSW Photovoltaics forecasting



// Energy with a future

// Zentrum f
ür Sonnenenergie- und Wasserstoff-Forschung Baden-W
ürttemberg (ZSW)

Thank you for your attention!



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