IEA Task 25 Meeting

Improvement of the Power System Reliability by Prediction of Wind Power Generation

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- Introduction
- Prediction Methods
- Model Accuracy Advantages and Improvements
- Extended Operational Control
- Outlook

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Wind Energy Use in Germany

20,850 MW
18,600 WT

as of 04/2007

Energy Production

26.4 TWh in 2005 – Wind Index 89 %
30.3 TWh in 2006 - Wind Index 90%
17.7 TWh in 2007 (Jan – Apr)
System operators viewpoint

Transmission System Operators Tasks

• Power and frequency control (primary/secondary control)
• Reliable grid operation
• Operate balance perimeter of RES

Need of Information und Tools

• Load flow calculation tools
• Short circuit calculation tools
• Grid Condition Monitoring
• Current Data and Forecasts of Distributed Generation (esp. wind power)
**Prediction Methods**

**Models and Tools for TSOs**

**Step 1**:  
**Online model** calculates from few measured windfarms the current power for all plants

**Step 2**:  
**Prediction model** calculates on the basis of the current power of all plants and the weather forecast the future wind power feed-in

**Accuracy** in the statistical average:  
> 94% for the D+1 forecast  
> 96% for the 4 hours forecast

**Applications**:
- **E.ON-Netz (1999)**
- **Vattenfall Europe Transmission (2003)**
- **RWE Transportnetz Strom (2002)**
- **EnBW Transportnetze (2006)**

**Wind Power Management System (WPMS)**
Calculation of **current power output** of each grid square by evaluation of all representative power signals

\[ P_{sum} = \sum_{i} P_i \]

considered parameters: **distance, roughness, control systems**

\[ P_i = P_{capi} k_i \sum_j s_j A_{ij} P_j \]
Prediction Methods

Calculation of **expected power output** of each grid square by evaluation of all representative wind farm power output predictions using NWP models and **Artificial Neural Networks**.
Prediction Methods

Artificial Neural Networks

\[ \hat{P}(t) = g \left( \sum_{j=1}^{m} A_j g \left( \sum_{k=1}^{n} w_{jk} x_k(t) \right) \right) \]

Support Vector Machines

\[ f(w_t) = \text{sign} \left( \sum_{\text{support vectors}} P_i \alpha_i K(w_i, w_t) \right) \]
Model Accuracy Advantages and Improvements

Continous improvement of model accuracy
Model Accuracy Advantages and Improvements

Two approaches are in operational use:

- Physical modeling
- Statistical approach (mathematical modeling, AI-methods)

+ New: Hybrid models

**Accuracy (RMSE) for wind farms in Germany:**

- flat terrain: 10%
- complex terrain: 12-14%
- very complex terrain: 20%
- offshore wind farms: 12%
Model Accuracy Advantages and Improvements

- use of high resolution data of different NWP-models (LMK of German Weather Service DWD with 2.8*2.8 km grid)
- WEPROG ensemble weather prediction model (MS-EPS)
- additional measured wind speed and power data
- methods to determine optimal input parameters
- expert prediction models for different weather situations
- classification methods to determine weather situations
Assumption: Improvements of model accuracy are superpositional

- Improvement of numerical weather prediction (NWP) models 10-15%
- Combination of different NWP models and classification of weather situation 15-20%
- Wind farm specific selection of prediction models 8-10%
- Selection of optimal input parameters 8-10%

Total improvement 35-40%

Reduction of wind farm prediction error from 15% to 9% – 9.75% (RMSE)
Extended Operational Control

Wind generation management by E.ON Netz, VE-T, E.DIS, E.ON Avacon, ...
Improvement by use of sub-grid area forecasts
Extended Operational Control

Dena Grid Study:

2015: Grid expansion and reinforcement

but

further penetration without intervention in operation of RES/DG is not possible
Extended Operational Control

One value for one hour for the entire control zone!
Extended Operational Control

Clustering and assignment of wind farms to HV-nodes

Calculation of intermediate and expected wind power in-feed to high voltage nodes (substations)
Extended Operational Control

Wind Farm control strategies:

- Generation management
- Reduction of gradients
- Supply of reactive power
- Supply of balancing power
- Improvement of wind power feed-in scheduling

Advanced Control:

- Represent geographical distributed wind farms as one wind power plant for the system operators purposes
- Wind Farm Cluster Management
Extended Operational Control

Four operation modes of the WCM result from the required control strategies for wind farms:

- Active Power Limitation
- Supply of Reactive Power
- Supply of Balancing Power
- Scheduling

Embedded wind farm cluster management system
Extended Operational Control

Field Test in Lower Saxony with onshore wind farm

Cluster A

Cluster B

Wind Farm

- 110-kV-bus
- 380 kV-bus
- 110 kV grid
Extended Operational Control

**Spain**

- **Distribution level**
- **Transmission level**

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**REE Grid Control**

- Servers
- Grid security parameters
- GEMAS Grid calculations
  - Overload, Short-Circuit

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**Command: Cluster B 100 MW**

**REE Grid Control**

- **Renewable Energies Centre (CECRE)**
  - **WCMS (ISET)**
    - **TSO Level**
      - **WFO 1**
        - WCMS - Wind Farm Operator Level (ISET)
      - **WFO 2**
        - WCMS - Wind Farm Operator Level (ISET)
      - **WFO 3**
        - WCMS - Wind Farm Operator Level (ISET)

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**WindGrid**

- **Cluster A**
- **Cluster B**
- **Cluster C**

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*Figure: Monitoring and command control flow for the WCMS in Spain*
Outlook

Extra Large Scale Virtual Power Plants (XLSVPP)

Pooling of wind, CHP, storage devices, and special conventional power plants to generation clusters

with

fast and precise adjustment by modern ICT and innovative generation management
Outlook

Leistung [MW]

Zeit
Thank you for your attention!