Wind Energy Forecasting

Tools and Techniques

by

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Presentation Plan

- Wind power in India
- Need of forecasting
- Overview-wind power prediction system
- Global experience
- Indian experience
- Benefits
- What can be done?
- Summary
Wind Power in India…..(1)

- More than 9500 MW installed till Sep. 2008
- Above 4000 MW in Tamil Nadu alone
- 82% of capacity addition since April 2002
- High growth rates recorded in last three years
- Average capacity addition of 1700 MW/yr for last 3 years
- High concentration in South Regional grid
- 10500 MW capacity addition planned in 11th plan by MNRE, total assessed potential 48,000 MW- 100000 MW
- Annul market to rise to 5000 MW by 2012
- Production capacity 10000+ MW under set up till 2010
- Present WTG manufacturers/suppliers nos. 9, to scale up to 25 by 2010
Wind Power in India...(2)

- National wind resource monitoring & demonstration programme
- National guidelines for tariff and interconnection for captive & third party sales
- Policy framework to push indigenisation
- Restructuring of power sector and emergence of ERCs
- Consolidation of wind energy stakeholders
- Emergence of EA 2003, and Textile Industry Investments
- Operationalisation of Kyoto Protocol
- % fixation and fixed tariff regime mandated by ERCs
- Mandated by ERCs
- Transparency

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Wind Energy Variability – the challenge!

GH Forecaster Hourly Power Evaluation
Forecast Horizon T + 24 hrs

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Typical load curve of Southern Region

- **Summer**
- **Winter**
- **Monsoon**
- **Evening Peak**
Typical load curve of Southern Region...(2)
Concept of Forecasting

MET. INST.  
ON-LINE DATA  
MODEL  
OUTPUT  
LAYOUT  
POWER CURVE
Need of forecasting

- Performance requirements for a forecasting - need of both the grid operator and the wind energy generators

- Wind energy generators - the priority is to minimize the deviation between forecasted and actual plant output

- **First priority**: To anticipate changes in wind production as accurately as possible in very short time (up to few hours ahead)

- To enable the Load Dispatch Centers (LDCs) to manage the grid operations in an optimal fashion

- **Second priority**: To forecast the wind generation for the next day - to enable the LDCs to schedule the reserve capacity as efficiently as possible

- Practiced in Denmark, Germany, Spain, U.K. and U.S.A.
Time Scale of Forecasting

- **Very short-term** (0-6 hrs) is related to the prediction of small scale atmospheric features in the vicinity of wind farm.

- **Short-term** (6-72 hrs) is related to the prediction of regional atmospheric features.

- **Medium range** (3-10 days) is related to the prediction of continental, hemispheric and global systems.

- Today the number of tools are available internationally for wind power forecasting considering these time scales.

- Most of the existing power prediction systems are based on the results of numerical weather prediction (NWP) systems.

- There are two approaches to transform the wind prediction given by NWP into a power prediction namely- statistical and physical.
Basic System of Forecasting
Basic System of Forecasting...(2)
Basic System of Forecasting...(3)
Overview of Wind Power Prediction System

- Site Data
- Site wind forecast model
- Wind Forecast
- Power model
- Power forecast

- Weather forecast
- Compare with results and update model
Basic Elements of Forecasting

- Numerical Weather Prediction system (NWP):
  - As input for wind power predictions
    - Statistical systems
    - Physical systems

- Site Topography
- SCADA
Most of the existing power prediction systems are based on the results of NWP. Extrapolate the actual state of the atmosphere using the laws of Physics. Wind speed and wind direction: most important variables. Simulate the development of the atmosphere by numerically integrating the non-linear equations of the motions starting from the current atmospheric state. Requires continuous mapping of the real world on a discrete 3-Dimensional computational grid. The resolution of numerical grid is finite, so NWP cannot simulate processes such as influence of orographic structures of terrain, localized thermal processes at sub-grid scale. Macroscopic effects of the sub-grid processes are modeled without considering the microscopic details. Thus, NWP models account for atmospheric behavior from larger scale e.g. 1000 km extension down to scale of the order of 10 km.
Numerical Weather Prediction (NWP)…..(2)

- NWP provides the necessary input for power prediction system-both the physical and statistical.
- Due to their complexity and large amount of data collection, these are typically operated by national weather services and these services use one global model.
- The global model drives a local model with a higher spatial resolution centered around the home country of the weather service.
- Data formats and measuring cycles are standardized by the World Meteorological Organization (WMO), then global meteorological data is available to the weather services to set the initial conditions for their NWP models.
- The output of the NWP is then useful for the power prediction tools.
### NWP system in Europe

<table>
<thead>
<tr>
<th>Model name</th>
<th>Weather service</th>
<th>Resolution (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Globalmodell (GME)</td>
<td>German weather service (DWD)</td>
<td>60</td>
</tr>
<tr>
<td>Lokalmodell (LM)</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>Arpege</td>
<td>Meto France</td>
<td>19-250</td>
</tr>
<tr>
<td>Aladin</td>
<td></td>
<td>9.5</td>
</tr>
<tr>
<td>Hirlam</td>
<td>Sweden, Denmark, Norway, Spain, Iceland, Ireland, Finland, the Netherlands</td>
<td>10-50</td>
</tr>
<tr>
<td>ECMWF</td>
<td>European Centre for Medium Range Forecasts</td>
<td>40</td>
</tr>
<tr>
<td>Unified Model</td>
<td>MetOffice, UK</td>
<td>60-11</td>
</tr>
</tbody>
</table>
Statistical Systems

- Statistical system approximate the relation between wind speed prediction and measured power output and generally don't use predefined power curves.
- It derives the relation between predicted wind speed and measured power output without an explicit local refinement.
- The optimal weights/difference between the online measurements and the meteorological forecast are continuously re-calculated. This has the advantage the parameters are automatically adapted long-term changes in the conditions e.g. variations in roughness due to seasonal effects etc.
- Mathematical models which are combined to generate the prediction of the aggregated power output of the wind farms in a certain area.
- **Models:** WPPT developed by RISØ, Demark, ANN developed by ISET, Germany.

**Advantages**
1. Self-calibrating to inherent changes in the system
2. Incorporate site-specific conditions automatically
3. Includes small-scale influences

**Disadvantages**
1. Needs a lot of data to build the database
2. Requires accurate measurements
3. Site-specific
4. Expertise concerning the physics of the atmosphere is still necessary to select the meteorological variables e.g. thermal stratification
**Physical Systems**

Use of the concepts of atmospheric dynamics and boundary layer meteorology to carry out the spatial refinement of the coarse output of the NWP systems to the site-specific conditions

- Transformation of the predicted wind speed to the hub height of wind turbines

**Two classes:**

1. Numerical model-based on operational fluid dynamical simulations like NWP
   - 3 subclasses:
     - NWP models: 1000-10 km
     - Meso-scale models: 10-1 km e.g. MM5, GESIMA
     - Micro-scale models: several 100-0.01 m e.g. WAsP
   
2. Diagnostic models—use of parameterizations of the boundary layer
   - e.g. PREDIKTOR by R RISØ, Denmark

**Advantages**

- Based on physical parameters
- Not site-specific
- Individual atmospheric process can be systematically invested to optimize the model

**Disadvantages**

- Sensitive to errors due to erroneous initial information
## Global Scenario

<table>
<thead>
<tr>
<th>Name</th>
<th>Developer</th>
<th>Method</th>
<th>Input Data</th>
<th>In operation by July 2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prediktor</td>
<td>Riso National Laboratory, Denmark</td>
<td>✓</td>
<td>✓</td>
<td>X</td>
</tr>
<tr>
<td>Wind Power Prediction Tool Zephyr</td>
<td>IMM and University of Copenhagen, Denmark</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>✓</td>
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<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Oldenburg University Germany</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>e Wind™</td>
<td>True Wind Solutions, USA</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>SIPREOLICO</td>
<td>University Carlos III, Madrid, and Red Electrica de España</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Advanced Wind Power Prediction Tool</td>
<td>ISET, Germany</td>
<td>X</td>
<td>✓ (ANN)</td>
<td>✓</td>
</tr>
<tr>
<td>Honeymoon</td>
<td>University College Cork, Ireland</td>
<td>✓</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>GH Forecaster</td>
<td>Garrd Hassan, UK</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Indian scenario

- Though 4th position in the world, very low penetration of wind power to the grid as compared to European countries
- No independent forecasting system for wind power
- Biasing the wind power due to its variability
- Need to develop wind power prediction system suitable to Indian conditions

Benefits

- Generate desperately needed information and scientific evidence to support wind sector growth.
- Help in mainstreaming wind power sector in India and hence contribute in business expansion activities.
- Remove misconception of power sector officials and decision makers based on scientific study and thereby reduce resistance level from the SEBs, grid operators for integration. Help in smoothening business development activities.
- In general help in nationwide acceptance for wind power
Wind Power Forecast – Indian example
Hourly data 24 hours in advance

Optimal use of data to refine the forecasts
Plus detailed site modelling
Results in accurate final forecasts

<table>
<thead>
<tr>
<th>Date</th>
<th>GH Forecast</th>
<th>Actual Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>22-May</td>
<td></td>
<td></td>
</tr>
<tr>
<td>23-May</td>
<td></td>
<td></td>
</tr>
<tr>
<td>24-May</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25-May</td>
<td></td>
<td></td>
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<tr>
<td>26-May</td>
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<td>27-May</td>
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<tr>
<td>28-May</td>
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<tr>
<td>29-May</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30-May</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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Value of Forecasting in UK Market

Example hourly trades

<table>
<thead>
<tr>
<th></th>
<th>Trade 1</th>
<th>Trade 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forecast Energy (MWh)</td>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>Produced Energy (MWh)</td>
<td>70</td>
<td>45</td>
</tr>
<tr>
<td>Revenue from forecast (£)</td>
<td>1750</td>
<td>2100</td>
</tr>
<tr>
<td>Cost for energy shortfall (£)</td>
<td>0</td>
<td>-675</td>
</tr>
<tr>
<td>Revenue from additional energy (£)</td>
<td>500</td>
<td>0</td>
</tr>
<tr>
<td>Total revenue (£)</td>
<td>2250</td>
<td>1425</td>
</tr>
<tr>
<td>Revenue normalised by production (£/MWh)</td>
<td>32.14</td>
<td>31.67</td>
</tr>
</tbody>
</table>

Assumed energy prices

- Average revenue using forecasts £5/MWh higher than sell price

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What Can be Done?

- Study of wind power forecasting tools/models available internationally
- Study of requirements of Load Dispatch Centers (LDCs) from wind farm
- Discussion with national weather service provider and its collaborating agencies like IMD
- Discussion with the wind turbine manufacturers/developers
- Selection of forecasting and power prediction models considering the Indian conditions
- A project can be taken up on single wind farm or whole state level with available international service.
- Based on the pilot project, an independent forecasting system can be developed
**Summary (1)**

The assumption of a static wind climatology needs to be reconsidered in view of global and regional climate change patterns.

Typical “short term” forecast performance

1. 8 hours ahead: typical MAE: 5% (1 hr) to 15% (8 hr)
2. Next calendar day: typical MAE: 15% to 20% of installed capacity

State of the art real time hourly forecasts substantially outperform persistence and climatology forecasts from hour 1 to ~ day 5.
Commercially available wind forecasting capability can reduce the costs associated with day-ahead uncertainty substantially.

In one major study, state-of the-art forecasting was shown to provide 80% of the benefits that would result from perfect forecasting.

Implementation of wind-plant-output forecasting in both power market operation and system operations planning in the control room environment is a critical next step in accommodating increasing amounts of wind penetration in power systems.
A brief overview of forecast tools indicates that there is a large and diverse pool of tools that can be used to generate wind energy forecasts.

The challenge is to use the optimal set of tools and configurations for a specific forecast application.