The Parts of a Wind turbine, Construction and Integration

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Draft

• The elements of a wind turbine
• The construction of the wind power plant
• The building procedure
• Integration of wind energy into bulk power systems
Growing unit performance

Today:
120-160 m
3.5-5 MW
Limits: the sky

Past and present wind turbines

Future wind turbines?

Source: Adapted from EWEA (2009).
Parts of a wind turbine

- Rotor blades
- Anemometer
- Gearbox
- Generator
- Generator house
- Steel tower
- Low-med. volt. transformer
- Power electronics
- Cable
- Grid

Patra, 2012
Foundation
Transportation
Transportation
Craning

Wind Turbine Construction - Wind energy integration - Patra, 2012
Nacelle
## Trends

<table>
<thead>
<tr>
<th></th>
<th>traditional</th>
<th>up-to-date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower</td>
<td>steel</td>
<td>concrete</td>
</tr>
<tr>
<td>Height</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>Rpm</td>
<td>semi fixed speed</td>
<td>variable speed</td>
</tr>
<tr>
<td>Cut in</td>
<td>3m/s</td>
<td>2,5m/s</td>
</tr>
</tbody>
</table>
E-40 – E-82
New control paradigm: wind priority

**Traditional control:** Load demand $\rightarrow$ generation control on the base of the demand

**Wind priority:** we let generate all the wind plant, and we produce some more by the request

**Future:** intelligent generation and load harmonisation (Demand Side Management)
New control paradigm: wind priority

Traditional:
Control by the demand
- E.g. steam generation
- Turbine
- Generator

Wind:
Control by the wind speed and demand
- rotor blades
- generator
Indirect and direct driving

Lapát 30/min
Áttétel 1:50
Generátor 1500/min

Generátor 30/min

a)
b)
Connection of the generator to the grid

Appr. RPM
900-1000 changing

Fixed frequency (RPM)
Control: pitch, P,Q
Electrical connection: compact substation
Connection to 20 kV
Single line scheme
More details…

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Protection, measurements, settling, RTU
Connection between the tower and the compact substation
Power, voltage level and topology

- 1 unit: cca. 2 MW (0.8 – 3.5 MW)
- 20 kV for transmission 3-8 MW
- Wind park: 20-30 units -> 110/120 kV
- Special topologies: ring, tree, quadratic, meshed, etc.
- Security – geography – economy – ecology
Wind speed changes
by Jensen

\[
\frac{v_{estela}(d)}{v_0} = \frac{1}{2} + \frac{1}{2} \sqrt{1 - 2C_T(v_0) \left( \frac{D_0}{D(d)} \right)^2}
\]
„Wind shadow” – Wake effect decreasing speed – decreasing energy
(work of Javier Serrano)

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Micrositing - optimisation
(work of Javier Serrano)
Quadratic displacement, Burgenland, Austria
Line on the hill edge
Molina *moderna* de Aragón
Wind metering tower
Atienza, Spain
Near Calatayud, Spain
Near Calatayud, Spain
Near Calatayud, Spain
150 towers on this picture!
Kefalonia, Greece
Measurements
Characteristics, RPM, output power

Cut in

Power out

RPM

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Niederland, Cabo Verde, Burgenland (A), Portugal
Windpower plants in Hungary, 2006
Characteristics
Rotor blade

V90 (~44 m) MD 77 (37.5 m) 6.5 t!
Glassfiber – epoxi
Grafit fiber
FL MD77

- High security due to individual blade adjustment
- Combined planet spur wheel gear for high effectiveness
- Large disk brake as 2nd safety system
- Variable speed, double-fed asynchronous generator for high profitability
- Four azimuth driving motors for safe and stable wind direction tracking
- Robust and compact machine support with sound decoupling for the main components
Output curve FL MD 70/77 (measured)

Output [kW]

Wind speed [m/s]

FL MD 77

FL MD 70

MD 77
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Patra, 2012
## Characteristics measurements

<table>
<thead>
<tr>
<th>Wind [m/s]</th>
<th>Power P [kW]</th>
<th>Power coefficient Cp [-]</th>
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</thead>
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<tr>
<td>1</td>
<td>0.0</td>
<td>0.00</td>
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<tr>
<td>2</td>
<td>3.0</td>
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<tr>
<td>3</td>
<td>25.0</td>
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<td>4</td>
<td>82.0</td>
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<td>5</td>
<td>174.0</td>
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<td>6</td>
<td>321.0</td>
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<td>25</td>
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</table>
„Storm control”

- Diagram 1: Power curve of a wind turbine without ENERCON storm control.
- Diagram 2: Power curve of a wind turbine with ENERCON storm control.
Comparison

<table>
<thead>
<tr>
<th>Szélerőmű típusa</th>
<th>NORDEX</th>
<th>ENERCON</th>
<th>NORDEX</th>
<th>NORDEX</th>
<th>ENERCON</th>
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</thead>
<tbody>
<tr>
<td>Megnevezés</td>
<td>N29/250</td>
<td>E-40</td>
<td>N43/600</td>
<td>N64/1000</td>
<td>E-112</td>
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<tr>
<td>Névleges teljesítmény</td>
<td>kW</td>
<td>250</td>
<td>600</td>
<td>600</td>
<td>1100</td>
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<tr>
<td>Indulási szélegebesség</td>
<td>m/s</td>
<td>3-4</td>
<td>2,5</td>
<td>3-4</td>
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<td>Leállítási szélegebesség</td>
<td>m/s</td>
<td>25</td>
<td>25</td>
<td>25</td>
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<td>Lapátszám</td>
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<td>Lapáthossz</td>
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<td>13,4</td>
<td>19</td>
<td>19,1</td>
<td>26</td>
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<tr>
<td>Járókerék átmérője</td>
<td>m</td>
<td>29,7</td>
<td>44</td>
<td>43</td>
<td>54</td>
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<tr>
<td>Megfűvött felület</td>
<td>m2</td>
<td>693</td>
<td>1452</td>
<td>2290</td>
<td>10000</td>
</tr>
<tr>
<td>Tengelymagasság</td>
<td>m</td>
<td>30/40/50</td>
<td>65</td>
<td>43/50/60</td>
<td>60</td>
</tr>
<tr>
<td>Járókerék fordulatszáma</td>
<td>1/min</td>
<td>39,5–29,5</td>
<td>34–18</td>
<td>26,9–17,9</td>
<td>22–16</td>
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Bükkaranyos
Wind Turbine Construction - Wind Energy Integration
Patra, 2012
Erk
Inota
Mosonmagyaróvár - Levél
Szápár
Törökszentmiklós
System load ↔ wind production

A hazai villamosenergia-rendszer terhelése

MW
0 1000 2000 3000 4000 5000 6000 7000
1 3 5 7 9 11 13 15 17 19 21 23
óra

Szélerőmű kiadott teljesítménye

kW
0 50 100 150 200
idő

Balancing with CO$_2$
Feel the measure!

V27 – 225 kW  E-40 600 kW  E-48 800 kW
Feel the measure!

MD-77 1.5 MW  V-90 1.8 MW  E-70 2 MW
How many tower represents 1000 MW?

- V27 225 kW 4444 pcs
- E-40 600 kW 1666 pcs
- E-48 800 kW 1250 pcs
- MD-77 1,5 MW 666 pcs
- V-90 1,8 MW 555 pcs
- E-70 2 MW 500 pcs

A lot.
Wind energy integration
Energy production calculation

- If 1000 MW built in capacity operates in 1 year with 20% usage ratio
  - 365 days x 24 hours x 1000 MW x 0.2% = 1,752,000 [MWh] = 1.752 TWh
- In Hungary it is only 4.47% of the total consumption
- Not too much
Power ratio

It is much!

How the wind blows

- BEWAG experiences: gradient 60 MW/h
- 3 areas - 3 different wind blows
- Local autobalancing in the windpark
- Balancing between different areas
Sudden stop of wind power plants

- Too strong wind (over 25-30 m/s)
- Network faults
- Frequency problems

Is it really problem to loose 200 MW? – daily events

The network flexibility must be raised!

- Diversification
- Forecast
• Fault in Spain

• Storm in Denmark
2008. 04. 01. operation - BEWAG
The UTSIRA project

Diagram of a wind energy integration system:
- Wind turbine
- Electrolyser
- Fuel cell/H₂ engine
- H₂ storage
- Flywheel
- Battery
- PMSM
- Transformer
- Control & regulating system
- Fuel cell
- H₂ engine
- Grid
Hydrogen generation

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Central hydrogen generation – system operator control

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Where to find the control capacities?

Unused controllable capacities

Uncontrolled gas fired capacities
Co-control of gas engines and wind turbines
Wind generation + gas engine generation + balancing
Load of the gas engine

-20 -10 0 10 20 30 40 50 60 70 80 90
1 3 5 7 9 11 13 15 17 19 21 23
óra
%
Csoport hiba %
Gázmotor eltérés %
Gázmotor tervezett %
Gázmotor tényleges %

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Control Center for Renewable Energy (CORE)

- Iberdrola
- Toledo, Spain
- Virtual power plant
- Connection to the ISO
- On-line control of the wind towers
- Maintenance control
What helps the integration?

- Control of the windpark output
- Diversification
- Local control centers
- Intraday power exchange
American plans...

20% Wind Scenario - 305 GW by 2030

No fundamental barriers identified to achieving the 20% wind vision

Incremental Direct Costs of 20% Wind Vision Scenario

<table>
<thead>
<tr>
<th>Present Value Direct Costs (billion 2006$)*</th>
<th>Average Incremental Levelized Cost of Wind ($/MWh-Wind)*</th>
<th>Average Incremental Levelized Rate Impact ($/MWh-Total)*</th>
<th>Impact on Average Household Customer ($/month)**</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>$0.5/month</td>
</tr>
</tbody>
</table>

Conclusion

- The wind technology is cleared, this is the high time of the application
- The hot topics are the off shore plants
- The integration of the wind energy is the question of decision
- The present network structures was not planned and implemented for the trade and renewable generation

Have a good work!
Thanks for the attention!