Lowering the production costs of offshore wind energy to a competitive level

Lisbon
November 2013
Energy Center of the Netherlands
Experience with wind since 1974

Q7

OWEZ

WMC

EWTW

2 test locations

ECN

Schiphol

Den Helder

Amsterdam

Petten

10 km
A Wind of Change
Working with the industry

1. Turbine performance improvement
2. Component analysis
3. Software based analysis
4. Onshore development
5. Individual phase analysis

1. Wind farm performance improvement
2. Component analysis for wind farms
3. Simulated & Measured improvement
4. Offshore development
5. Integrated Phase Approach
Vision 2016 - A Wind of Change

ECN Wind Energy as world leader institute on

Innovative Solutions for Offshore Wind Power Plants

- Reduce cost of energy of offshore wind power plants
- World leading institute on innovative products and solutions
- The critical success factors are our world leading facilities
- State of the art wind farm services
Cost of energy reduction

Cost of Energy

€/kWh

Annual costs

O&M Costs

Depreciation

Financing costs & risks

WACC

Averaged Investment costs

Losses

Gross output

OUTPUT

1/ Annual production

Costs

40%

Cost of Energy

Δ Costs*: -27%

Δ OUTPUT: +21%

Δ Cost of Energy -40%

*Based on typical capital costs offshore wind farm: 25-35% O&M, 40-50% CAPEX, 20-30% financing costs

Losses

+21%

-25%

-25%

-10%

-33%

(0.9x0.75)

-25%

+40%
Offshore Wind Power Plants
The Netherlands is pushing ahead in wind.

The near future of offshore wind
- Fast growth of installed MW
- Larger turbines
- Further offshore
  - More wind to harvest
  - Out of sight, but
  - Far away
  - Deeper water
  - Harsh weather conditions

And still reduce 40% cost of energy in 2020!? (Target EU)

<table>
<thead>
<tr>
<th>Tender in</th>
<th>Capacity</th>
<th>Operational in</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>450 MW</td>
<td>2019</td>
</tr>
<tr>
<td>2016</td>
<td>600 MW</td>
<td>2020</td>
</tr>
<tr>
<td>2017</td>
<td>700 MW</td>
<td>2021</td>
</tr>
<tr>
<td>2018</td>
<td>800 MW</td>
<td>2022</td>
</tr>
<tr>
<td>2019</td>
<td>900 MW</td>
<td>2023</td>
</tr>
</tbody>
</table>

Source: Energieakkoord (socio-economic counsel SER)
Advanced Wind Farm Design
Integrated Wind Farm design & reducing the cost of energy

- Optimised wind farm focussed on:
  - Highest energy yield
  - Lowest cost of energy
  - Fully optimised farm layout
Mapping the weather
An essential first step

- Reliable data
  - Seasonal variations
  - Climate changes
- North sea wind map
  - Utilised by investors, wind farm developer and utility companies
  - Feasibility studies

Offshore locations

+/- 0.5 M/s of wind means the difference between a bad and an excellent investment
Selecting the right turbine
a good second step

Aerofoils and rotor design
Controller design
Drive train innovations
Support structure design

For higher yield and lower loads
Increased reliability & lower O&M
Reduced weight
Easy installation

SELECTING THE RIGHT TURBINE TO REDUCE THE COST OF ENERGY
Combining Wind and Electricity
the third step, getting complicated

Wake Losses:
\( \{P_{WT_1}, ..., P_{WT_N}\} = f(V_w, V_{dir}) \)

CAPEX
\( P_{\text{loss}} \) per component
\( P_{\text{fail}} \)

Annual Energy Production
Levelized Production Costs

Component database
- Loss models
- Prices
- MTBF, MTTR
Economical param.
Installation, logistics & Support
Fourth step, a costly one

Transport & monitoring

Logistics & harbour selection

Soil conditions & cable laying methods

Support selections
Offshore O&M
Fifth and most forgotten step
**Strategy III:**

<table>
<thead>
<tr>
<th></th>
<th>Availability [%]</th>
<th>O&amp;M Costs [€ct/kWh]</th>
<th>Total [M€]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Original assumption</td>
<td>91.7</td>
<td>2.13</td>
<td>87</td>
</tr>
<tr>
<td>2. 50% less spare transfers</td>
<td>94.1</td>
<td>1.97</td>
<td>75</td>
</tr>
<tr>
<td>improvement</td>
<td>2.62%</td>
<td>7.51%</td>
<td>€12M</td>
</tr>
</tbody>
</table>
Wind Farm Operational Excellence
1 Measurements
Correct measurements & analysis for the correct wind assessment
Measuring/monitoring the turbine & components in operation?

2 Analysis
Farm power output analyses (using the correct Wind, turbine, availability data)
Analysis for the individual components
Analysis of O&M scenarios
Analysis of the problem

3 Improvement
Is it possible to improve the power output? If so;
The most cost effective solution for the problem,
Possible solutions in short term and/or long term?

4 Implementation
New O&M strategy
Active wake control
Metmast maintenance,
Vessel access system
Wind forecasting
Turbine monitoring etc

Windfarm Operational Excellence
Offshore wind farm power performance assessment

Product / Service
Accurate and affordable assessment of the power performance of an offshore wind turbine without a mast
- Floating LiDAR
- Nacelle LiDAR
- Relation to IEC standards

Benefits for client
- Determination of under performance of wind turbine
- Proper action towards decent O&M
Active Wake Control
An ECN patent

Software analysis on variety of windfarms

Tests on 2MW Nordex turbines and scaled wind farm at ECN test site

Total farm efficiency!
Production increase from 0.5 to 5%
AND
Load reduction by 3%
Matching power output with demand

Electrical windfarm control

Wind Farm Controller

System Operator

balancing the windfarm and grid between demand and production
Optimising operations
Lowering the costs of energy
Wind Power Plant
Production Forecast: Structure

- Wind forecasting
- Park Operations
- Production loss due to standstill
- WTs not maintained
- Actual maintenance plan
- WTs failed
- WTs shut down for maintenance
- Wind effects
- WTs operating at reduced power
- Wave forecasting and equipment availability
- Planned maintenance (condition/calendar-based)
- Est. probability to execute all plans
Offshore wind farm trends

EWEA: 2012 European Offshore Statistics
Lowering the production costs of offshore wind energy to a competitive level

• Is it possible?
  – Yes, but requires an integrated approach
  – The entire life time has to be considered
  – Continued optimisation is required also during operations

• Future challenges
  – Further offshore
    – Harsher weather conditions.
    – Higher production
    – More complicated grid connections
  – More dedicated support for offshore windfarms
    – Vessels, harbours, turbine support
    – Specialised research and development
Innovative solutions
to lower the cost of energy

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