Der Winergy HybridDrive – Optimierung des Antriebssystems durch Integration der mechanischen und elektrischen Komponenten

September 2013 / Matthias Deicke
1. **Company Profile**  
   Facts and figures

2. **Drive Concepts**  
   Drive train concepts

3. **HybridDrive Design**  
   Concept

4. **HybridDrive Installation**  
   Different configurations of the drive train

5. **HybridDrive Specification**  
   Main data/options: journal bearings

6. **DT Efficiency/Cost of Energy**  
   Annual energy yield

6. **Testing/Project Status**  
   Components vs. System Testing

7. **Summary**  
   Questions
Mission

“Winergy will maintain its position to be the leading supplier of reliable wind drive train components. This will be accomplished through long term partnership with our customers.”

Market Position

- Global market leader for drive train components
- More than 70,000 gear units delivered
- Every 3rd wind turbine is equipped with Winergy components

Customer Base

Trustful partnership with all major wind turbine OEMs since 1981

Global Footprint

Winergy runs production and service facilities in all major markets globally.

- USA
- Europe
- China
- India

© Winergy –public-
Winergy’s history
Great achievements for the wind industry

<table>
<thead>
<tr>
<th>Year</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>70,000 gearboxes globally supplied</td>
</tr>
<tr>
<td>2011</td>
<td>Introduction of HybridDrive</td>
</tr>
<tr>
<td>2010</td>
<td>Introduction of Multi Duored gearbox</td>
</tr>
<tr>
<td>2009</td>
<td>Commissioning of new plant in Elgin, IL, USA</td>
</tr>
<tr>
<td>2007</td>
<td>Commissioning of 14 MW test bench</td>
</tr>
<tr>
<td>2006</td>
<td>Foundation of winergy Drive Systems Ltd. (Tianjin, China)</td>
</tr>
<tr>
<td>2005</td>
<td>Foundation of winergy Drive Systems Ltd. (Chennai, India)</td>
</tr>
<tr>
<td>2003</td>
<td>Introduction of 5 MW gearbox prototyp</td>
</tr>
<tr>
<td>2001</td>
<td>Foundation of winergy AG</td>
</tr>
<tr>
<td></td>
<td>Foundation of winergy Drive Systems Corp. Elgin, IL, USA</td>
</tr>
<tr>
<td>1991</td>
<td>First offshore wind park with winergy components</td>
</tr>
<tr>
<td>1981</td>
<td>Delivery of first specially designed wind turbine gearboxes</td>
</tr>
</tbody>
</table>
Winergy
Our Customers are supported by our Global Presence

Voerde, Germany
HQ

Tianjin, China

Elgin, IL, USA

Chennai, India
### Drive Train Concept

<table>
<thead>
<tr>
<th>Planetary stages drive train</th>
<th>Technical Facts</th>
<th>Facts of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Two-/three-stage gearboxes</td>
<td>Proven technology</td>
</tr>
<tr>
<td></td>
<td>Winergy sets standards in wind industry</td>
<td>Highest market share</td>
</tr>
<tr>
<td></td>
<td>500 kW – 7.5 MW</td>
<td>Extensive track record (&gt; 60,000 MW)</td>
</tr>
<tr>
<td></td>
<td>$i = 90 \ldots 110$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average: 1.5 – 2.5 MW</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Multi Duored</th>
<th>Technical Facts</th>
<th>Facts of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High power density</td>
<td>First installation of two prototypes in Bard wind turbines</td>
</tr>
<tr>
<td></td>
<td>Great serviceability</td>
<td>Duored technology known for many years in industry</td>
</tr>
<tr>
<td></td>
<td>Up-tower service and maintenance</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Two generators for variable output power and speed</td>
<td></td>
</tr>
<tr>
<td></td>
<td>8-fold power splitting</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$i &gt;&gt; 135$</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 MW – 12 MW</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HybridDrive</th>
<th>Technical Facts</th>
<th>Facts of interest</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Highest overall drive train efficiency</td>
<td>First two prototypes with Fuhrländer/ W2E Wind to Energy GmbH</td>
</tr>
<tr>
<td></td>
<td>Modular setup for easiest serviceability</td>
<td>3.0 MW prototype ready at end 2q2012</td>
</tr>
<tr>
<td></td>
<td>Super compact for flexible concepts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3 MW – 7.5 MW</td>
<td></td>
</tr>
<tr>
<td></td>
<td>$i = 35 \ldots 42$</td>
<td></td>
</tr>
</tbody>
</table>
HybridDrive
Winergy’s most Powerful 14 MW Test Bench (mark)
1. **Company Profile**  
   Facts and figures

2. **Drive Concepts**  
   Drive train concepts

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   Concept

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   Different configurations of the drive train

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   Main data/options: journal bearings

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   Annual energy yield

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   Questions
Drive Trains for Wind Turbines
Scaling Rules/Driver for Development

- $T \sim D^3$
- $\text{Mass} \sim T$
- $\text{Investment} \sim \text{mass}$
- $\text{Earnings} \sim \text{kWh}$
- $\text{Earnings/investment} = \text{ROI} \sim 1/D$

Source: Andreas Mascioni / Vensys Energy AG / VDI Konferenz 2010 / Entwicklung der getriebelosen Windenergieanlagen
Drivers for Wind Turbine Design:

- Technology driven: DFIG, PM, hybrid, standard, ...
- Law driven: Grid codes, renewable energy law
- Market driven: Onshore, Offshore, ROI, investors
- Philosophy driven: Direct drive, geared concepts, low – medium voltage

Cost of energy
<table>
<thead>
<tr>
<th>Speed Level</th>
<th>Fixed speed</th>
<th>Variable speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>High speed</td>
<td>Asynchronous</td>
<td>Asynchronous</td>
</tr>
<tr>
<td></td>
<td>Squirrel cage</td>
<td>Squirrel cage and converter</td>
</tr>
<tr>
<td></td>
<td>Pole changing</td>
<td>DFIG and converter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>DFIG and resistor in rotor circuit</td>
</tr>
<tr>
<td>Intermediate speed</td>
<td>100 – 700</td>
<td>Electrically-excited generator and converter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PEM generator and converter</td>
</tr>
<tr>
<td>Low speed</td>
<td>Asynchronous</td>
<td>Asynchronous</td>
</tr>
<tr>
<td></td>
<td>Squirrel cage</td>
<td>Electrically-excited generator and converter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PEM generator and converter</td>
</tr>
</tbody>
</table>
HybridDrive
Concepts: Multi Duored/Power Split

- Cost reduction (weight drive train, weight nacelle)
- Serviceability ➔ in nacelle (modular design)
Construction SCD – Technology
main components

- Hub
- Gearbox
- Generator

Conceptual design SCD – Turbine
technical specification

- Frame of gearbox and generator on force flow path
- Bearing, gearbox and generator with almost the same diameter
- Rotor bearing as two-row taper roller bearing
- Two-stage planetary gear with i=21.7
- 1st stage on the plane of the rotor bearing
- 1st stage with five planet wheels
- Planet wheels mounted on flex pins
- Permanent magnet synchronous generator
- Water cooling cover in generator housing
- All other systems supported inside the head carrier
- All components are completely encapsulated
- Nacelle cover necessary
HybridDrive
Concepts: Multibrid/AREVA

Multibrid M 5000

Planetary compact gear with integrated rotor bearing and generator
General Electric (GE)

- Generator hinter dem Turm
- Übernahme von Scanwind
- 110 m Rotordurchmesser bei 4 MW Nennleistung
- keine Azimutbremsen mit ständig, unmittelbarer Windrichtungsnachführung

Source: Friedrich Klinger / Forschungsgruppe Windenergie HTW des Saarlandes / VDI Konferenz 2010 / Was macht getriebelose WEA zum Erfolgskonzept?
HybridDrive
Concepts: HybridDrive

2-stage gear technology + PMG or EESG medium speed generator = Winergy HybridDrive

- Low weight
- High efficiency
- Serviceability
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   Concept

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   Annual energy yield

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   Components vs. System Testing

7. **Summary**  
   Questions
HybridDrive
Drive Train Matrix

<table>
<thead>
<tr>
<th>Speed Range</th>
<th>Fixed speed</th>
<th>Variable speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>High speed 700 – 2000</td>
<td>Squirrel cage</td>
<td>Squirrel cage and converter</td>
</tr>
<tr>
<td>Intermediate speed 100 – 700</td>
<td>Squirrel cage and converter</td>
<td>DFIG and converter</td>
</tr>
<tr>
<td>Low speed 10 – 100</td>
<td>DFIG and resistor in rotor circuit</td>
<td>Electrically-excited generator and converter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PEM generator and converter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Electrically-excited generator and converter</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PEM generator and converter</td>
</tr>
</tbody>
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HybridDrive Concept
HybridDrive Concept
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   Drive train concepts

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   Concept

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   Main data/options: journal bearings

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7. **Summary**  
   Questions
Great Serviceability through a Modular Design

- A design comprising three modules allows the individual elements to be simply removed/installed:
  - 1st gear stage
  - 2nd gear stage
  - generator
- The internal service crane of the nacelle can be used to transport these modules instead of employing an external crane.

Benefits

Reduction of service complexity and cost minimization for service work
1. **Company Profile**  
   Facts and figures

2. **Drive Concepts**  
   Drive train concepts

3. **HybridDrive Design**  
   Concept

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7. **Summary**  
   Questions
## General data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Rated main shaft power PN</td>
<td>3200.00 [kW]</td>
</tr>
<tr>
<td>Rotor diameter d</td>
<td>118 [m]</td>
</tr>
<tr>
<td>Power coefficient cp</td>
<td>0.45</td>
</tr>
<tr>
<td>Rated wind turbine power</td>
<td>3001.556 [kW]</td>
</tr>
<tr>
<td>Rated wind speed</td>
<td>10.915 [m/s]</td>
</tr>
<tr>
<td>Rated wind turbine speed</td>
<td>12.367 [rpm]</td>
</tr>
<tr>
<td>Tip speed</td>
<td>76.407 [m/s]</td>
</tr>
<tr>
<td>Rated main shaft torque</td>
<td>2470.962 [kNm]</td>
</tr>
<tr>
<td>Gearbox ratio i</td>
<td>39.43</td>
</tr>
<tr>
<td>Type of gearbox</td>
<td>Two-stage</td>
</tr>
<tr>
<td>Rated generator speed</td>
<td>487.621 [rpm]</td>
</tr>
<tr>
<td>Tip speed ratio Lambda</td>
<td>7</td>
</tr>
<tr>
<td>Type of drive train</td>
<td>B</td>
</tr>
</tbody>
</table>

* B, permanent magnet synchronous generator, 2-stage planetary gearbox, IGBT*
Generator design for 2500 kN:\n
<table>
<thead>
<tr>
<th></th>
<th>IEC I</th>
<th>IEC II</th>
<th>IEC III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>710 V</td>
<td>710 V</td>
<td>710 V</td>
</tr>
<tr>
<td>Frequency</td>
<td>84.9 Hz</td>
<td>77.9 Hz</td>
<td>73.1 Hz</td>
</tr>
<tr>
<td>Speed</td>
<td>566 rpm</td>
<td>519 rpm</td>
<td>487 rpm</td>
</tr>
<tr>
<td>Output power</td>
<td>3670 kW</td>
<td>3360 kW</td>
<td>3160 kW</td>
</tr>
<tr>
<td>Current</td>
<td>3 * 1070 A</td>
<td>3 * 1010 A</td>
<td>3 * 965 A</td>
</tr>
<tr>
<td>Efficiency</td>
<td>98.05 %</td>
<td>98.15 %</td>
<td>98.20 %</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.93</td>
<td>0.91</td>
<td>0.89</td>
</tr>
</tbody>
</table>

Service type   | S1        |
Number of poles | 18        |
Direction of rotation | Left      |
Type of enclosure | IP54      |
Ambient temperature | -30°C … +50°C |
Type of cooling | IC71W    |
Coolant temperature | 55°C      |
Flow rate | 120 l/min       |
Coolant      | Water-glycol  |
Net weight   | Xxx kg     |
Moment of inertia | 720 kgm²   |
Utilization | F / F     |
Winding connection | star     |
Winding type | Double layer, integer slot winding |

HybridDrive specification

- Gearbox specification
- Generator specification
- Converter specification
- Brake specification
- Cooling specification
- Lubrication
- Painting, etc.

Requirements for H-Drive

- Decoupling of the DT from mech. forces
- Elastic coupling
- Insulated bearings
- Dry oil sump lubrication
- Serviceability integrated

Database for WINERGY
HybridDrive concept
HybridDrive
Anti-friction Bearings or Journal Bearings
1. **Company Profile**
   Facts and figures

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   Different configurations of the drive train

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7. **Summary**
   Questions
Drive Train Efficiency

- Geared DFIG
- Directdrive
- Geared PM
- HybridDrive

Efficiency vs Wind speed / [m/s]

- 85.00%
- 86.00%
- 87.00%
- 88.00%
- 89.00%
- 90.00%
- 91.00%
- 92.00%
- 93.00%
- 94.00%
- 95.00%

Wind speed / [m/s]:
- 3.5
- 8.5
- 13.5
- 18.5
Annual Energy Yield

*) specific assumptions are made
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7. **Summary**  
Questions
HybridDrive System
Test Procedure/General Set Up

- Certification guideline GL2010
- Component Certification
- Type test before Sep. 2012

- Component-specific tests
- Sub-Systems
  - Generator – Inverter
  - Gearbox – Generator
- Complete System

INVERTER NOT WINERGY’s SCOPE of SUPPLY
HybridDrive System

Test Procedure/Components

Gearbox:
Generator: (sine-wave test):

Component-specific tests

Sub-Systems
Generator – Inverter

Sub-System
Gearbox – Generator

Complete System

Gearbox
Generator
Inverter (FC)

HybridDrive System

INVERTER NOT WINERGY’s SCOPE of SUPPLY
HybridDrive
Mechanical Test – Planning vs. Realization
Gearbox:

- 200 h overload test
- Loaded with = 36.56 kNm (180 % x T_rated)
- Load sharing
- Temperature development
- Vibration
- Noise
Component-specific tests

Sub-Systems
Generator – Inverter

Sub-System
Gearbox – Generator

Complete System

HybridDrive System

Generator + Inverter:
Back-to-back test setup

Gearbox
Generator
Inverter

INVERTER NOT WINERGY’s SCOPE of SUPPLY
Performed Tests:

- No-load as generator
- No-load test open stator
- Sine-wave test
- Cold resistance of stator winding
- No-load characteristic
- FFT of no-load voltage
- Running „short circuited“
- Sudden short circuit
- Vibration
- Noise (body sound/air sound)
- Mechanical tests
- Temperatures (winding/magnet)
- Shaft voltage
- Bearing voltages
- ...

- Back-to-back
- Heat run tests (different load points)
- Cooling pressure drop
- Noise
- Vibration
- Sudden short circuit
- Shaft voltage
- Bearing voltage
- ...

HybridDrive
Test Procedure/Electrical Sub-System
HybridDrive Test Procedure

Component-specific tests

Sub-Systems
- Generator – Inverter

Sub-System
- Gearbox – Generator

Complete System

Gearbox + Generator:
- Climate chamber
- Cold temperature starting procedure

HybridDrive System

Gearbox

Generator

Inverter

INVERTER NOT WINERGY’s SCOPE of SUPPLY
Gearbox:
• Minimum temperature – 40 °C
• Starting torque
• Starting procedure
• Heating
• Oil distribution at low temperature

Oil Supply System:
• Starting procedure
• Heating

Generator:
• Starting procedure
• Heating
• Cooling system temperature
HybridDrive System: "Complete System" Test

Component-specific tests

Sub-Systems
Generator – Inverter

Sub-System
Gearbox – Generator

Complete System

HybridDrive System

Gearbox

Generator

Inverter

INVERTER NOT WINERGY’s SCOPE of SUPPLY
HybridDrive
Test Procedure/FULL System Test
**HybridDrive Temperature Rise Test**

- Different load points
- All temperatures below specified limits

<table>
<thead>
<tr>
<th>Nr. / No.</th>
<th>Vergang / Item</th>
<th>Laststufe / Load stage</th>
<th>Probelauf / Test run</th>
</tr>
</thead>
<tbody>
<tr>
<td>49D</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Style / Stage</th>
<th>Generator - Drehzahl / Speed</th>
<th>Generator - Generator speed</th>
<th>Generator - Generator power</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7.6</td>
<td>200</td>
<td>4.8</td>
</tr>
<tr>
<td>2</td>
<td>8.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.1</td>
<td>12.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.2</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.1</td>
<td>12.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>11.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.3</td>
<td>12.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8.7</td>
<td>10.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.1</td>
<td>12.6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.2</td>
<td>14.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
HybridDrive SYSTEM efficiency vs. speed
(T = 40%, 60%, 80% 100% of Trated)

- SYSTEM efficiency @ rated point >96 %
- Very high partial load efficiency

*) Preliminary testfield data @ 20°C Coolant temperature.
HybridDrive
Vibration Test/T1-T4/Acceleration [m/s²]

<1 m/s² in all conditions

TEST passed
HybridDrive Vibration Test/T1-T4/Speed [m/s]

<0.3 mm/s in all conditions

TEST passed
LESS noise than other systems

HybridDrive
Noise Measurement

TEST passed

Rotor speed (vs. Torque)

Torque [kNm]

Rotor speed [1/min]

characteristic curve P<Pnenn
characteristic curve P=Pnenn

< 92dB(A)
< 93,1dB(A)
< 93,6dB(A)
< 92,0dB(A)
< 91,8dB(A)
< 91,8dB(A)
< 83,7dB(A)

< 92dB(A)
< 93,1dB(A)
< 93,6dB(A)

< 92dB(A)
< 93,1dB(A)
< 93,6dB(A)
< 92,0dB(A)
< 91,8dB(A)
< 91,8dB(A)
< 83,7dB(A)
LESS noise than other systems

TEST passed
Conclusion:

- HybridDrive tests finalized
- Test results as expected or slightly better
  - Heat run test ➔ o.k., as calculated
  - Efficiency ➔ slightly better than calculated
  - Noise ➔ better than calculated
  - Vibration ➔ better than expected
- HybridDrive system test successfully completed.
- Investigation of measurements is going on …
  … some “possible improvements” have been found.
- For details please contact Winergy
  or watch: HybridDrive Movie
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<td></td>
<td>Squirrel cage and converter</td>
<td>DFIG and converter</td>
</tr>
<tr>
<td></td>
<td>DFIG and resistor in rotor circuit</td>
<td>Electrically-excited generator and converter</td>
</tr>
<tr>
<td>Intermediate speed 100–700</td>
<td>Asynchronous</td>
<td>Synchronous</td>
</tr>
<tr>
<td></td>
<td>Electrically-excited generator and converter</td>
<td>PEM generator and converter</td>
</tr>
<tr>
<td>Low speed 10–100</td>
<td>Electrically-excited generator and converter</td>
<td>PEM generator and converter</td>
</tr>
</tbody>
</table>
HybridDrive
First prototype / T10x / 3MW / 120m

Source: W2E Wind to Energy
HybridDrive
First prototype / Facts

Project name: T10x
Type: W2E-120/3fc
Design: IEC 61400-12 IEC 2a
Power: 3MW
Rotor diameter: 120 m
Tower: Steel 100m
Concrete hybrid 140m
HybridDrive
2011 first market introduction
First **Winergy HybridDrive** for Customer Fuhrlander on Hanover Fair, April 2012

(People: E. Wen Jibao, Angela Merkel und Joachim Fuhrlander)
HybridDrive
Hanover 2013 ... ready for operation
Thank you for your Attention!

Matthias Deicke
Winergy AG
Head of Electrical Systems

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Fax: +49 (2871) 92-2487

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