Mitsubishi Heavy Industries
Wind Power Technologies

2012.5.31
Offshore Wind Turbine Project Development Department
Wind Turbine Business Division
Power Systems HQ

MITSUBISHI HEAVY INDUSTRIES, LTD.
Company Profile

low-carbon Society

High-efficiency power generation
- Nuclear power plants (EUPWR: 1700MW, ATMEA1: 1100MW)
- Fast Breeder Reactor, nuclear fuel cycle
- Pebble Bed Modular Reactor

Renewable Energy
- Wind turbines (onshore & offshore)
- Solar (photovoltaic & thermal) power generation
- Geothermal power generation
- Hydropower (including micro water wheel)
- Wave power, tidal power

Energy-saving products
- Heat pumps
- Eco-houses
- Enhancement in iron making efficiency

Innovation in transportation system
- EV-related business
- ITS
- M R J (Mitsubishi Regional Jet)
- Eco-ships
- LRT, HSST

Innovation in other infrastructures
- Seawater desalination
- Vegetable plants
- Alternative fuels (coal, bio)

Innovation in electricity infrastructure
- Smart grid
- Lithium-ion battery
- V2G (Vehicle to Grid)
- H2G (Home to Grid)

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MHI Products

Cruise Ship  Cable Stayed Bridge  Regional Jet  Ferris Wheel  H-II Rocket

Combined Cycle Power Plant  Conventional Thermal Power Plant  Wind Turbine

Flue Gas Desulfurization  Diesel Generator  Printing Machine  Air Conditioning Unit
# Mitsubishi Wind Turbine : MWT-Series

## MWT62/1.0

- **Operation**: Market launch in 2003
- **Rated Output**: 1000 kW
- **Rotor Diameter**: 61.4 meters
- **Hub Height**: 69/60 meters

## MWT92/2.4 / MWT95/2.4 / MWT100/2.4

- **Operation**: Market launch in 2008
- **Rated Output**: 2400 kW
- **Rotor Diameter**: 92/95/100 meters
- **Hub Height**: 70/80 meters

### Power Regulation
- Full Span Pitch Control

### Wind Class
- IEC Class IIA, (IIB)
Mitsubishi WIND TURBINES in The World

(As of February 2010)

- Wales, UK
  - 300kW x 103 units

- Winkra, Germany
  - 450kW x 1 unit

- Korea
  - 1000kW x 3 units

- India
  - 300kW x 6 units

- Portugal
  - 500kW x 20 units

- Bulgaria
  - 1000kW x 35 units

- Oregon, USA
  - 600kW x 83 units
  - 1000kW x 41 units

- Japan Domestic
  - 290 units, Total 246 MW

- Indonesia
  - 250kW x 1 unit

- Palm spring CA, USA
  - 600kW x 111 units

- Buena Vista CA, USA
  - 1000kW x 38 units

- Wyoming, USA
  - 1000kW x 50 units

- Hawaii, USA
  - 250kW x 37 units

- New Mexico, USA
  - 1000kW x 80 units
  - 1000kW x 90 units
  - 1000kW x 120 units

- Texas, USA
  - 1000kW x 764 units

- Peru
  - 450kW x 1 unit

- Portugal
  - 500kW x 20 units

- Bulgan
  - 1000kW x 35 units

- Korea
  - 1000kW x 3 units

- Mexico
  - 250kW x 1 unit

4,056 units / 4,124 MW
Wind Farm in USA.

Texas
2400kW × 84 units = 201.6MW
2400kW × 118 units = 283.2MW
Total 202 units 484.8MW
California, Palm Springs 2001 600kW × 111 units

Hollywood movie "Mission Impossible III" has taken here.
Colorado, Ceder Creek 2007 1000kW × 221 units
Bulgaria 2008 1000kW × 35 units

Developed by Mitsubishi Power Systems Europe
Ehime Japan 2003 1000kW × 11 units

Developed by Mitsubishi Heavy Industries
Offshore wind turbine

MHI has been developing offshore wind turbine through support by NEDO (New Energy and Industrial Technology Development Organization) and BIS (UK department of Business, Innovation and Skills)
Japan sea vs North sea

- Japan is surrounded by deepest sea in the world.
- Most of EEZ (Exclusive Economic Zone) are very deep (>1,000m depth)
- Very few sea area are suitable for Offshore wind turbine.
Japan sea vs North sea

- Av. wind speed > 8m/s
- Av. sea depth 50~70m

Fig. 2.7, North Sea water depths (source: National Oceanographic Data Centre NOAA).
First Offshore wind in Japan (NEDO prototype)

- Operation: 2012 Summer
- Site: 3km off coast of Choshi (CHIBA pref.)
- Depth: 11m

Modified MWT92/2.4
Type: Hydraulic transmission variable speed
Rated capacity: 7MW
Wind class: IEC 61400 class-1 offshore
Generator type: Synchronous brushless
Rated speed: 1,000 rpm
Demonstration start from Jun 2013
Off shore wind turbine is getting more larger output because of stronger wind speed and site availability.

Key technology for scale up from 2MW to 7MW

- Longest blade with carbon composite
- Modular design by hydraulic drive train

<table>
<thead>
<tr>
<th>Turbine Size</th>
<th>output</th>
<th>diameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>On shore</td>
<td>1MW</td>
<td>62m</td>
</tr>
<tr>
<td></td>
<td>2~3MW</td>
<td>100m</td>
</tr>
<tr>
<td></td>
<td>5~7MW</td>
<td>160m</td>
</tr>
<tr>
<td></td>
<td>10MW</td>
<td>180m</td>
</tr>
<tr>
<td>Off shore</td>
<td>7.0MW</td>
<td>rotor: more than 165m blade: more than 80m Nacelle weight: approx 550ton Hub height: 110~120m</td>
</tr>
</tbody>
</table>
Our target is the **Highest CF**, **Less cost**, **High availability** with following concepts.

- **Longest blade** *(Rotor Diameter: 165m more)*, **Highest CF** *(CF: over 55%)*, **Large output** *(7MW)*
  
  Our target CF is more than 55% which is the highest CF at this moment.

- **High generated power quality, Grid conformity**
  
  Adoption of brushless synchronous generator (constant speed control), similar to thermal power plant.

- **High reliability and robustness by adoption of hydraulic drive**
  
  Exclusion of gearbox and converter which minimizes serious failure for existing wind turbine.
  
  High availability and robustness of operation sustainability even under the partial cylinder failure.
  
  Partial replacement rather than the whole replacement in comparison with a geared type.

- **Low maintenance cost**
  
  High maintainability for parts replacement just performed inside nacelle (lifting inside tower).

- **Less cost**
  
  Commercially Viable and bankable with hydraulic equipment, material and synchronous generator.
  
  (Low procurement risk by exclusion of rare earth)

- **Modular design**
  
  Enlargement is relatively easier and more flexible (short development term, low development cost) by modular design of hydraulic drive.
Concept of 7MW

Hydraulic transmission

Rotor ≥ 165m
Hub height approx 90m
Height over the sea Approx 20m

A380
Wing 33m
Width 79.8m
Length 73m
Height 24.1m

Brushless Synchronous generator
Digital control variable Hydraulic pump
Digital control variable Hydraulic motor

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Edinburgh, Scotland
30 employees; 5 Phds
Sparked by research on wave power at University of Edinburgh
Licensing business model
Supporting licensees from concept to product

**Patents**
- Granted: >20 patents (>8 families)
- Applications: >30 new families
Advantage of DDT hydraulic drive train

- not needed gear box
- adoptable standard synchronous generator
- not needed frequency converter

<table>
<thead>
<tr>
<th>Digital Displacement®</th>
<th>Standard synchronous generator</th>
<th>Not needed</th>
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</thead>
<tbody>
<tr>
<td>DDT® (Hydraulic transmission)</td>
<td>Mechanical gearbox</td>
<td>Grid</td>
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</table>

<table>
<thead>
<tr>
<th>Geared</th>
<th>Induction or PM synchronous generator</th>
<th>Frequency converter</th>
<th>Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical gearbox</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Direct Drive</th>
<th>Heavy PMSG generator</th>
<th>Frequency converter</th>
<th>Transformer</th>
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<tbody>
<tr>
<td>Not needed</td>
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Easy to access to site

Quay berth for ocean-going ship

Business cluster for Wind business

Bremerhaven

Cuxhaven
Floating type offshore wind turbine

MHI is developing floating type offshore wind turbine through support by METI (Ministry of Economy, trade and Industry)
Mitsubishi Floating type Offshore Windturbine

Location: Fukushima offshore
Type: Hydraulic transmission variable speed
Rated capacity: 7MW
Demonstration start from 2014
Fukushima floating type Offshore Wind turbine Project

Wind turbine Float
Hitachi IHI-MU
Fuji 2MW Mitsui
MHI 7MW MHI
(Not fixed) IHI-MU

2013
Substation
4column semi submerge
4column semi submerge
Advanced spar
Thank you for your attention.