Technology (continued)

- Hubs
- Drive Trains
- Generators
- Towers
- Foundations
- Lightning Protection
- Obstruction Marking

Paul Gipe, wind-works.org
Hubs

Teetered-Delta 3-Butterfield

Paul Gipe, wind-works.org

ESI 80, Palm Springs, CA
Hubs
Teetered-Pitch Linked

Windflow 500
Gebbies Pass, NZ

Paul Gipe, wind-works.org
Hubs
Cantilevered

Paul Gipe, wind-works.org
Hubs
Fixed (But Adjustable) Pitch
Hubs
Variable Pitch

Paul Gipe, wind-works.org
Drive Trains
Traditional Danish

Paul Gipe, wind-works.org
Drive Trains
Main Shaft-Traditional
Drive Trains
Integrated (Small-Medium)

Paul Gipe, wind-works.org
Drive Trains
Integrated (Large)

Paul Gipe, wind-works.org
New Drive Trains

Paul Gipe, wind-works.org
Drive Trains
Multiple-Output Gearboxes

© Clipper Wind

Paul Gipe, wind-works.org
Buffalo, New York
Generators
Dual-Induction

- Dual Speeds
- Simple
- Rugged
- Cheap

Paul Gipe, wind-works.org
# Generator Pole Switching (RPM)

<table>
<thead>
<tr>
<th></th>
<th>50 Hz</th>
<th>60 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-pole</td>
<td>1500</td>
<td>1800</td>
</tr>
<tr>
<td>6-pole</td>
<td>1000</td>
<td>1200</td>
</tr>
</tbody>
</table>

Paul Gipe, wind-works.org
Generators
Wound-Rotor (Doubly-Fed)

Paul Gipe, wind-works.org
Generators-Variable Speed

- Better Performance  
  Mostly Hype

- Lower Loads  
  Major Plus in Large Turbines

- Ability to Correct Power Factor

- More Expensive

- More Complex

- And, Don’t Forget the “Patent”

Paul Gipe, wind-works.org
Generators-Variable Speed

- “Opti” Slip (10%)
- Doubly Fed Generators
  Widely Used in Germany
  Inverter Handles Only a Portion of Power
- Full Variable Speed
  Inverter Handles Full Power
  Full Benefits of Variable Speed
  Enercon, Lagerwey, & PMGs

Paul Gipe, wind-works.org
Towers

- Guyed
  - Small Turbines
  - Large Turbines
- Freestanding (Cantilevered)
  - Lattice
    - Small Turbines
    - Large Turbines
  - Tubular
  - Concrete
- Hinged

Paul Gipe, wind-works.org
Towers-Guyed Small Turbines

Paul Gipe, wind-works.org
Towers-Guyed Lattice
Small & Medium Wind Turbines

Paul Gipe, wind-works.org
Towers-Guyed
Large Wind Turbines

Paul Gipe, wind-works.org
Towers-Lattice

Paul Gipe, wind-works.org

© Nordex
Towers-Tubular Small Turbines

Paul Gipe, wind-works.org
Towers-Tubular Medium & Large Wind Turbines

Paul Gipe, wind-works.org
Towers-Hinged Small Turbines

Paul Gipe, wind-works.org
Foundations

- Piers
  - Lattice Towers
- Spread Footing
- Monopile
  - Solid
  - Hollow with Fill

Paul Gipe, wind-works.org
Foundation Monopile Hollow with Fill

Paul Gipe, wind-works.org

© Neal Emmerton
Foundation Bolts

Paul Gipe, wind-works.org
Lightning Protection
Nacelle Lightning Rod

Paul Gipe, wind-works.org

© Nordex
Obstruction Marking

- **Height Limits**
  - 200 ft USA
  - 100 m Europe

- **Lights**
  - Red (night?)
  - Strobe (Day)
  - Impacts

- **Painting**

Paul Gipe, wind-works.org
Obstruction Marking

Paul Gipe, wind-works.org
Operations & Maintenance

• Large Turbines
  Formerly by Quarter
  Now Once/year

• Small Turbines
  Once/year

• Large Turbines
  Complex & Rotating Schedules
  Visual Inspections
  Moving Parts

• Electronic Controls
  Largest Single Cause of “Nuisance” Trips

Paul Gipe, wind-works.org
Good Housekeeping

• Little Items Make a Big Difference on a Million-Dollar Wind Turbine!
Operations & Maintenance
Check Welding

© Lagerwey

Paul Gipe, wind-works.org
Operations & Maintenance

• Condition Monitoring
  Large Turbines
• w/o Condition Monitoring, No Insurance
• w/o Insurance, No Financing
• Enercon “Partner” Program
  Other Manufacturers Following Suit

Paul Gipe, wind-works.org
Fall Protection

- Body Harness
- Shock-Absorbing Lanyard
- Double-Acting Snap Hook
- Positioning Belt is Only for Positioning

Paul Gipe, wind-works.org
Safety

- Helmet
- Gloves
- Harness
- Radio

Paul Gipe, wind-works.org
Aerial Lifts

Paul Gipe, wind-works.org
Ladder Fall Protection

- fall protection device
- climbing cable
- lock
- hook

© Lagerwey

Paul Gipe, wind-works.org
Ladders

Paul Gipe, wind-works.org
Steps

Paul Gipe, wind-works.org
Secure Rotor Locking

Rotor Hub

© Lagerwey

Paul Gipe, wind-works.org
Secure Rotor Locking

Paul Gipe, wind-works.org

© Nordex
Secure Rails & Attachments

© Nordex

Paul Gipe, wind-works.org
Access Doors

Tararua, NZ

© Nordex

Paul Gipe, wind-works.org
Secure Access Doors

It’s Windy Out There

- Lock to Prevent Unauthorized Access
- Latch to Prevent Door Closing
- Interior Release To Prevent Confinement
- Ventilation Louvers

Paul Gipe, wind-works.org
Safety . . .

• Anti-Climb Guards
• Shaft Guards
• Two-Person Crews
• Regular Reviews
• Myth Busting
  “Never Fall Ascending”
  “Want to Jump Free”