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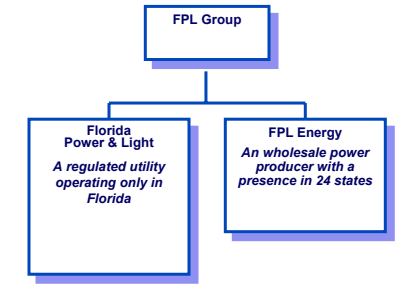
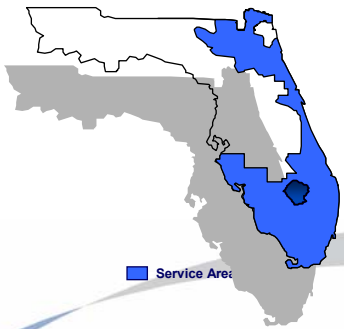
Wind Generation
Part I – Planning, Design & Operations

Jack Hochheimer, FPL Energy, LLC

Providing Safe, Reliable Power for 75 Years

FPL Group — one of the nation's largest providers of electricity-related services





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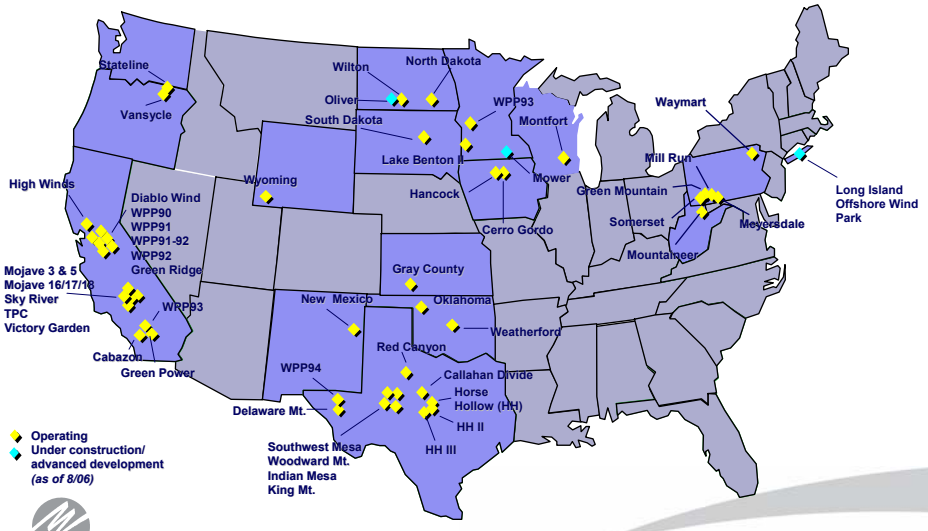
FPL Energy Wind Portfolio



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FPL Energy – Wind Facts

- Largest U.S. generator of wind power
- 47 wind farms in 15 states
- More than 3,600 net megawatts
- Approximately 28 percent of FPL Energy 's total generation
- 2005 pollution offsets that would have otherwise been released into the atmosphere from other sources of power generation:
  -- nearly 4.9 million tons of carbon dioxide
  -- more than 13,000 tons of sulfur dioxide
  -- nearly 9,000 tons of nitrogen oxide

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Fun Wind Facts

- The earliest known windmills were in Persia (Iran) and looked like large paddle wheels.
- Today, the largest wind turbines in the world have blades longer than a football field.
- A typical horizontal wind turbine stands as tall as a 20-story building and has three blades that span 200 feet across.
- One wind turbine can provide enough electricity for about 300 homes.
- Wind turbines in the U.S. generate 17 billion kilowatt-hours per year of electricity, enough to serve 1.6 million households.
- Wind energy is generated in 30 different states. Those with the most wind production are California, Texas, Minnesota, Iowa and Wyoming.
- The U.S. ranks third in the world in wind power capacity, behind Germany and Spain.

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Wind Generation Technology

- Asynchronous machines (1.5 to 5 MW ea.)
  - Wound rotor induction machines with external variable resistor to control slip
  - Doubly-fed induction machines
  - Induction machines with full AC-DC-AC converter
- Reactive capability
- Ability to “ride-through” extreme voltage excursions

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Schedule Considerations

- Production Tax Credit Expiration/Renewal
- Relatively slow interconnection process
  - Studies
  - Agreements
  - Upgrades
- Wind projects go in very fast
  - Hancock 100MW project - 80 days from groundbreaking to full COD.

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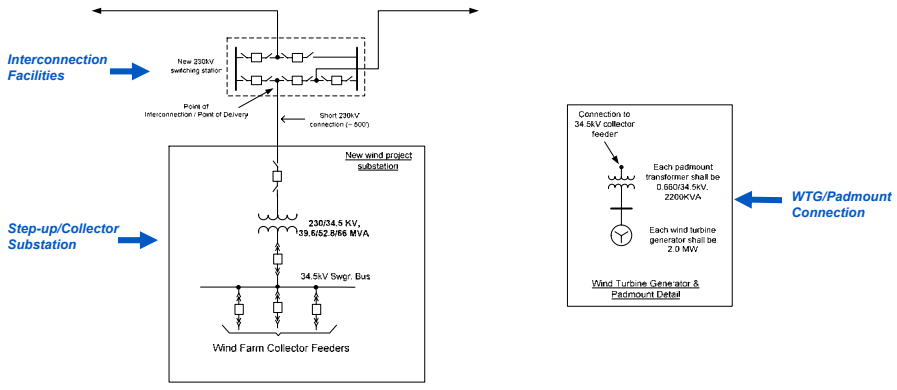
Interconnection & Step-Up Facilities



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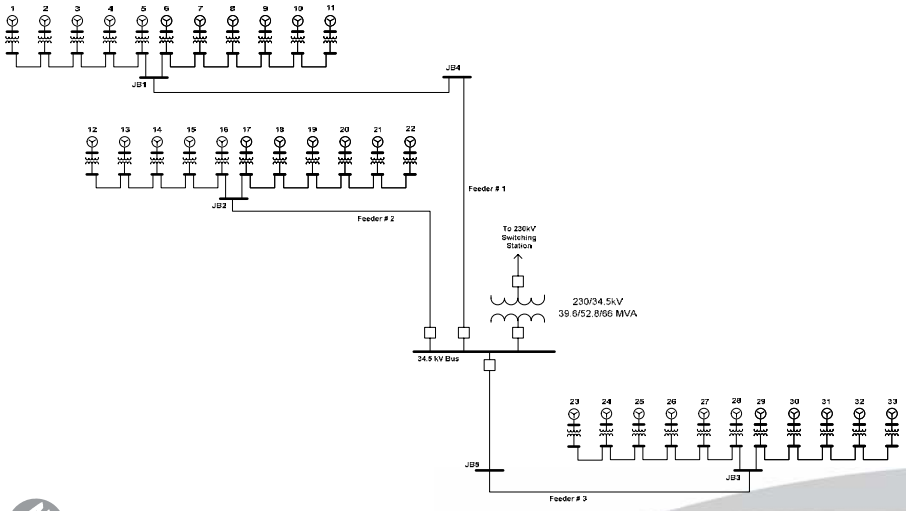
Collector System



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Collector System

- Large modern wind farms have many miles of medium voltage collector feeders.
- Real & reactive losses.
  - Typical real losses: 2-1/2%
  - Reactive losses much higher
    - Feeder reactances
    - Substation step-up transformer reactance
    - Individual wind turbine padmount transformers
- Voltage gradients across feeders may lead to high voltages at feeder ends – which may limit generator reactive output

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Wind Turbine Generator Models

- Relatively recent/strong interest in stability performance.
- Lack of PSLF and PSS/E library models has added time and cost to impact studies.
- Many models now available due to efforts of Suppliers, PTI, GE and Consultants.
- Model validation efforts underway.

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Collector Equivalents

- Need to simplify wind farm model
  - Reduce number of buses, branches, transformers, generators
- Accuracy of equivalent
- Current efforts by NREL / PNM / FPLE / GE / UWIG

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Dynamic Voltage Deviations

- Occasionally, internal protection trips WTG's for low voltage during nearby faults
- FERC/NERC/AWEA standards:
  - 15 % of nominal: 2006/07 projects
  - 0 %: after 2007
- Solutions (all add cost to projects)
  - WTG control mods
  - Fast VAR injection

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Reactive Capability

- Some newer WTG's have reactive capability.
- Transmission Providers expect synchronous machine type performance.
- Wind projects often tie into weak grid locations.
- Possible need for supplemental reactive.
- Feeder voltage regulation considerations.

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Communications & Control

- Remote command and control of plant output;
- Telemetry communication for “automatic” forecasting/scheduling.

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Thermal Considerations

- Wind generation is often at its lowest levels during Summer peak periods.
- Thermal cooling of conductors and equipment due to high winds may allow higher ratings during periods of peak wind production.
- Some Transmission Providers are willing to take higher ambient wind into account..

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Operational Considerations

- Transmission system availability
  - Wind farms often in the boondocks >>> flimsy grids
  - Planned & forced outages
- Reactive capability of modern WTG's can provide needed voltage support to weak grid areas.

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QUESTIONS ???

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