Distinguished Lecture

IEEE Power & Energy Society and A Practical View of the US Wind Market

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Vice President — Power Systems Services
S&C Electric Company

Overview

- IEEE Power & Energy Society
- Wind Energy
  - Overview
  - Development in the United States
  - The Turbine and Tower
  - Engineering and Constructing the System
- Conclusion

PES is Strong, and Wants to Serve More People

PES and its membership

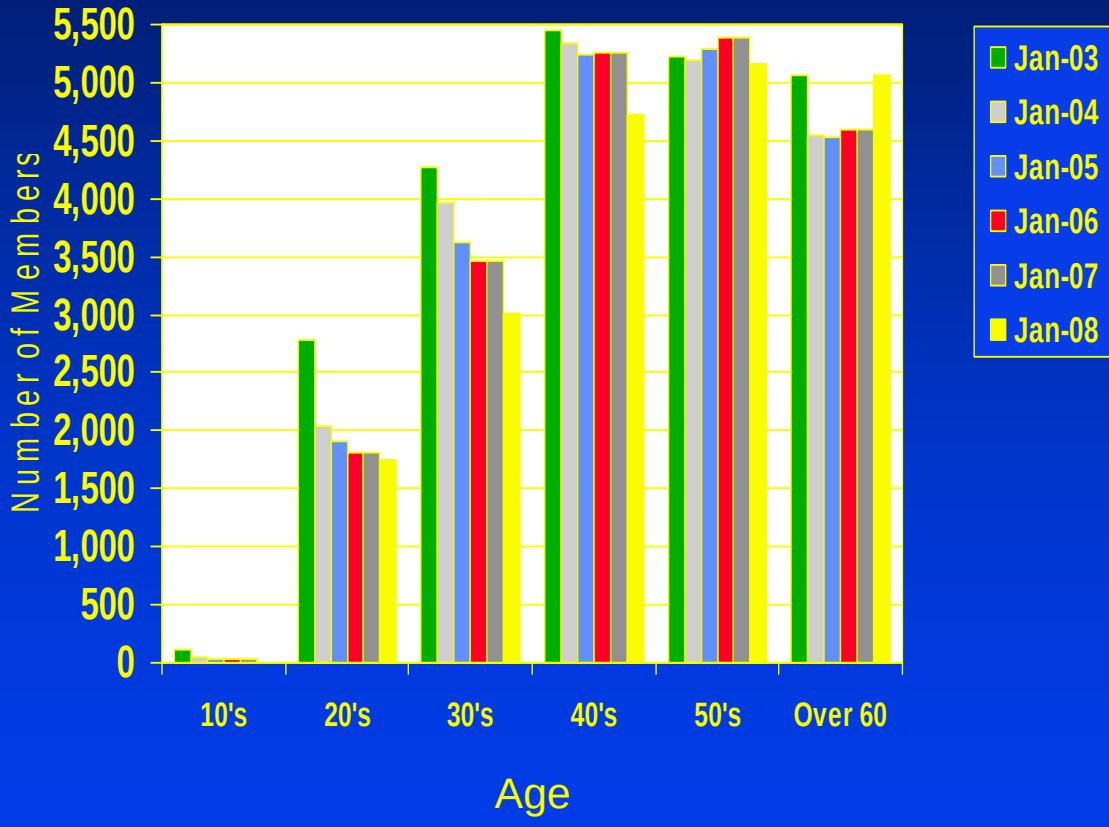
Demographically Challenged

- Members < age 50 are decreasing
- Approximately 8 years older than IEEE members

2007 Student Survey

- Energy and Power engineering is exciting, critical and relevant
- 48% were “more” interested in Power & Energy Society

Age of PES Membership by Decade



Celebrating our Future…
With 125 Years of Tradition

A Changing Power and Energy World …

Growing population & energy density

Cost of energy … fuel supply & demand

Increasing environmental requirements

Escalating security concerns

Heightened investor demands

Driving power generation technology

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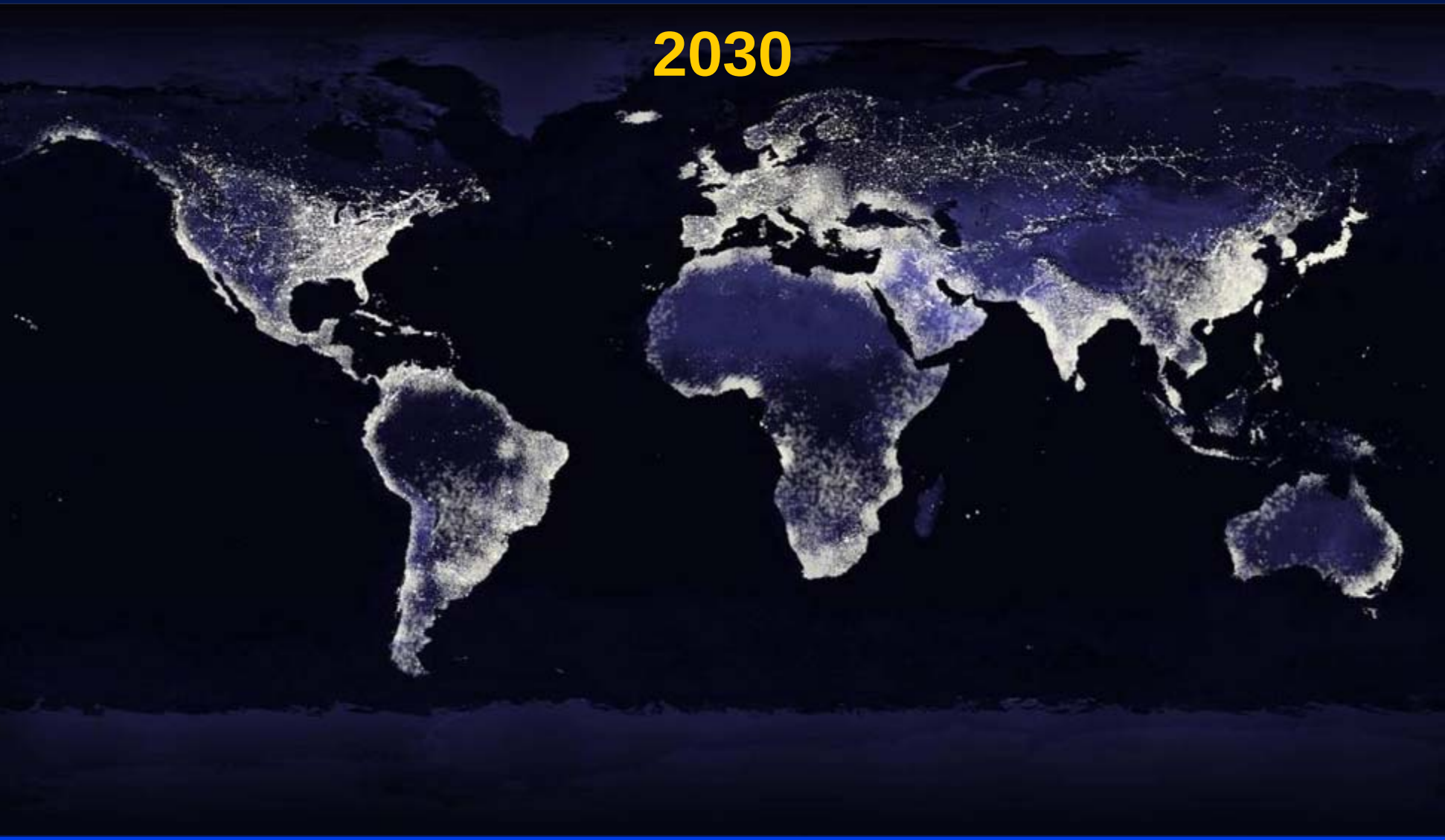
USMA, May 20th, 2008

2008

2030



Technologies Needed to Address Challenges

- Global warming and climate change
- Energy efficiency
- Plug-in hybrid electric vehicles
- Renewable energy sources
- Smart grids
- Distributed generation
- The carbon footprint

Fuel Diversity is Critical

Diverse




Gas
Coal
Nuclear
Oil
Geothermal
Biomass
Wind
Solar
Hydro

+

Efficient

Efficiency
Reliability
Emissions

Driving cost of electricity down

Affordable, reliable & environmentally responsible

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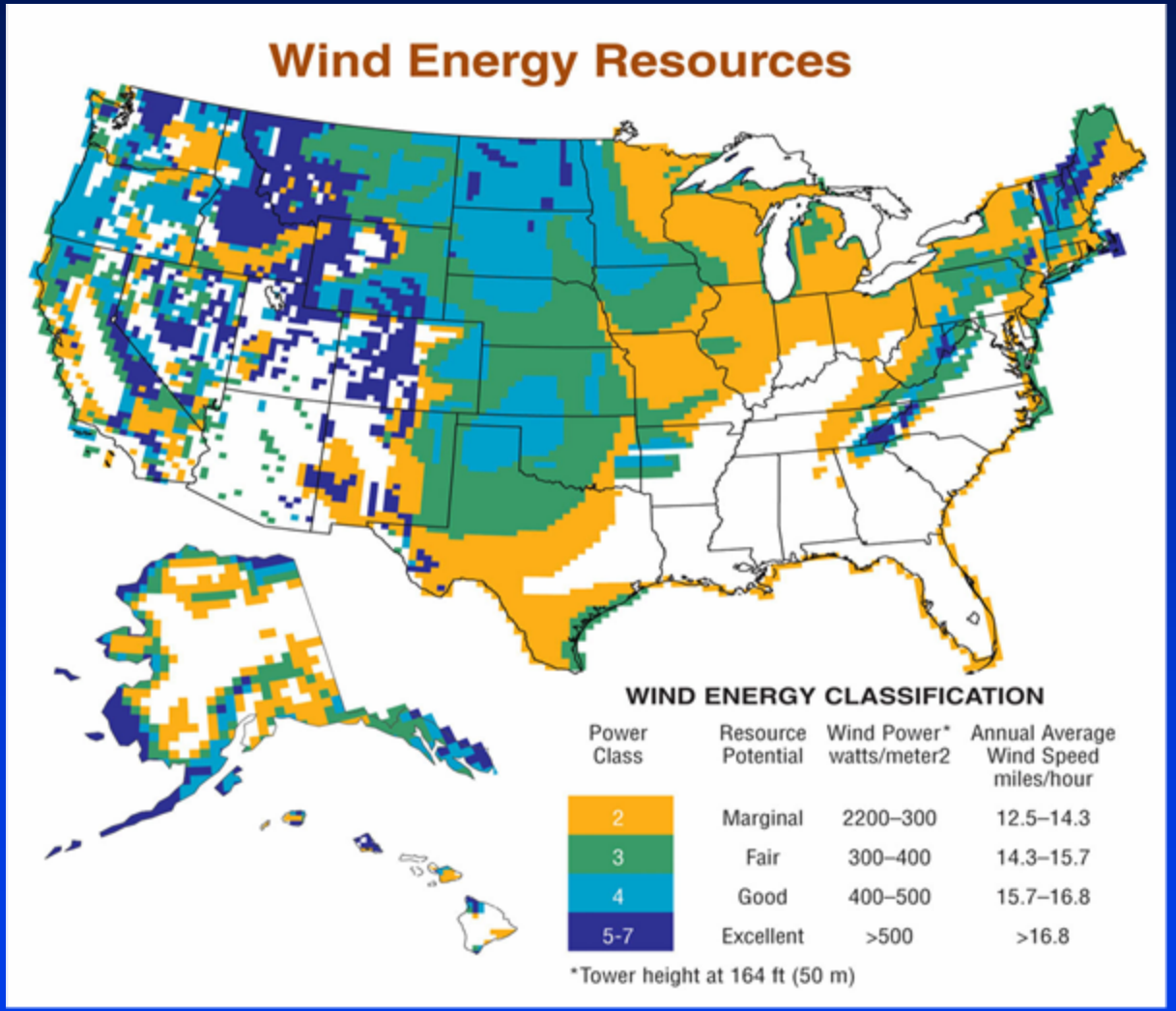
An All American Resource

Rank	State
1	North Dakota
2	Texas
3	Kansas
4	South Dakota
5	Montana
6	Nebraska
7	Wyoming
8	Oklahoma
9	Minnesota
10	Iowa
11	Colorado
12	New Mexico
13	Idaho
14	Michigan
15	New York
16	Illinois
17	California



Source: AWEA

Wind Power is Steadily Growing

- Growing worldwide
  - 25% annual growth from 2002 – 2006
  - Over 15,000 MW of new capacity added in 2006
  - Installed capacity at the end of 2006 was over 75,000 MW
    - ~50,000 MW in Europe: installations shifting to off-shore
    - ~11,600 MW in the United States
- Growing in the United States
  - In the last 5 years, average annual growth rate of 22%
  - In both 2005 and 2006, the second-largest source of new generation capacity in the US trailing to natural gas
  - Provides less than 1% of total electricity consumption
  - Analysis for 20% energy saturation is underway

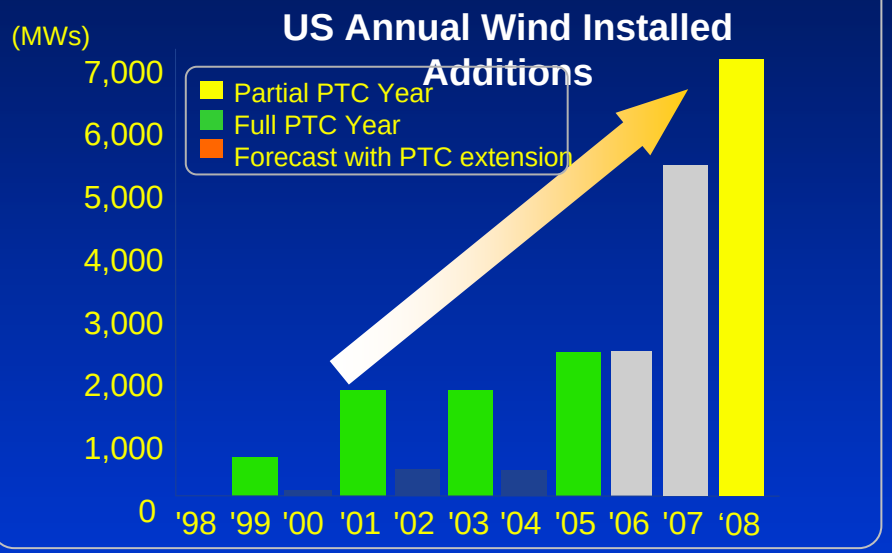
Source: AWEA and IEEE Power & Energy Magazine

Driving Forces Behind the Growth

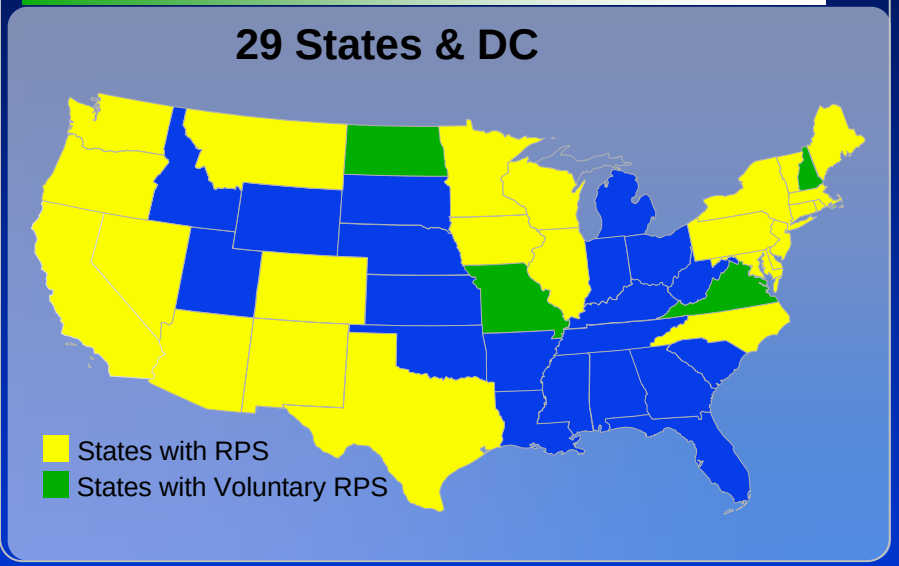
- Wind's Steadily Improving Economics
  - Federal production tax credit
  - Bigger turbines
  - More productive turbines
  - Larger project size
- State and Federal Policy Initiatives
- Benefits to Utilities from Wind in Mix
  - No fuel cost
  - No environmental costs
  - Popularity with customers
- Fossil Fuel Prices Increasing
- Fossil Fuel Price Volatility

Successful Policy … Driving Growth

Federal Production Tax Credit



Renewable Portfolio Standards



- **Aggressive global targets**

✓50 countries installing wind power

✓65 countries with renewable targets

✓ US … 20% Wind ‘30

✓ EU … 20% Renewable Energy ‘20

✓ China … 30 GW Wind ‘20

✓ India … 12 GW Wind ‘12

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Economic Development

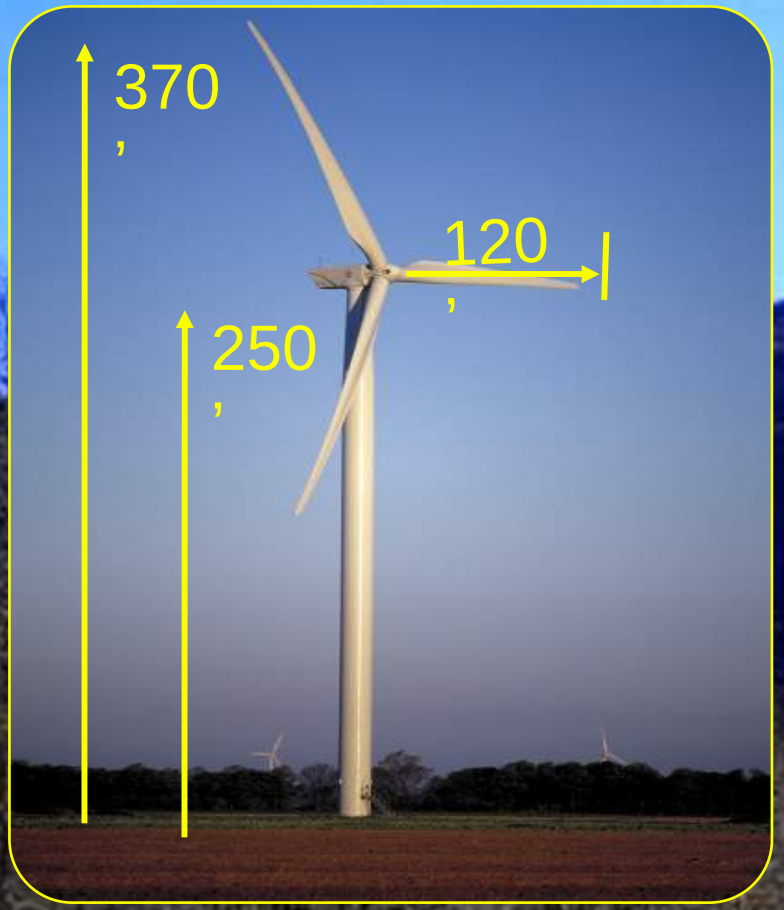
- Typical income from land leased for agricultural use:
  - $150 - $200 per acre
- Typical profits from wind:
  - Typically 25-40 acres per turbine
  - 4 turbines per acre of land taken out of production
  - Royalties of $2,000 - $4000 per machine
  - Income of $8,000 per acre of land taken out of production
- Valuable source of property tax
- Jobs: ~1 skilled O&M job / 10 turbines

Typical Wind Turbines

- Rotors:
  - Three-blades
- Nacelle:
  - Points the turbine into the wind
- Tower:
  - Supporting base
- Output:
  - Typically 1.5 MW per turbine
  - Controlled by rotating the blades
  - Wind requirements:
    - 12 to 30 mph
    - Blades feather at 50 mph
  - Capacity factor now exceeding 35%

Source: IEEE Power & Energy Magazine and UWIG

Typical 1.5MW Turbine



A single 1.5MW turbine …

- Can power 500 homes
- Total weight is 155 Tons
- Has blade sets that sweep the area of a football field
- Tip speed = 200 MPH

Environmentally Sound

100MW Wind Farm*
Displacement of:

- 3 million tons of coal
- 1.7 billion cubic meters of natural gas
- 3.6 million barrels of oil

Emission Reductions

- 200,000 tons CO2/yr

Equivalent to:

40,000 cars off the road/yr

50,000 acres of planted forested land

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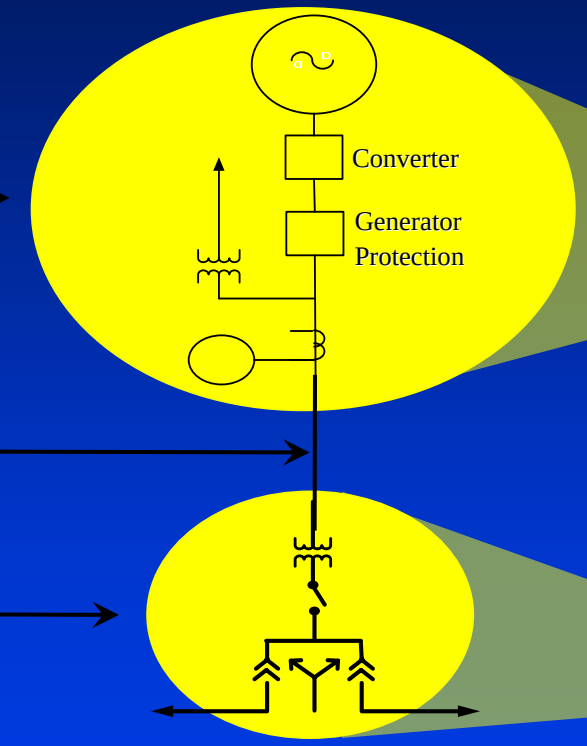
General Layout of the Collector System

Inside the Nacelle

Tower Voltage
575/690V or 35kV
(Cable or Bus)

Pad-Mounted
Transformer
(Internal or External)



To Adjacent Transformers
Or Towers


Vestas
Ø 3620
TS
52070
124950

Trend for Larger Turbines and Projects

- Larger Turbines:
  - The average generating capacity of a turbine installed in 2006 was 1.6 MW up from 0.76 MW in 2000
  - The largest wind turbine installed in 2006: 3 MW at Rio Vista, CA

- Larger Projects:
  - Eight of 45 US wind projects done in 2006 were over 100 MW
  - Largest in the United States
    - 735 MW Horse Hollow Wind Energy Center in Texas
    - A FPL Energy project
  - Largest in Canada
    - 200 MW Prince Wind plant in Sault Ste Marie, Ontario
    - S&C Electric was the Substation and Collector Systems EPC

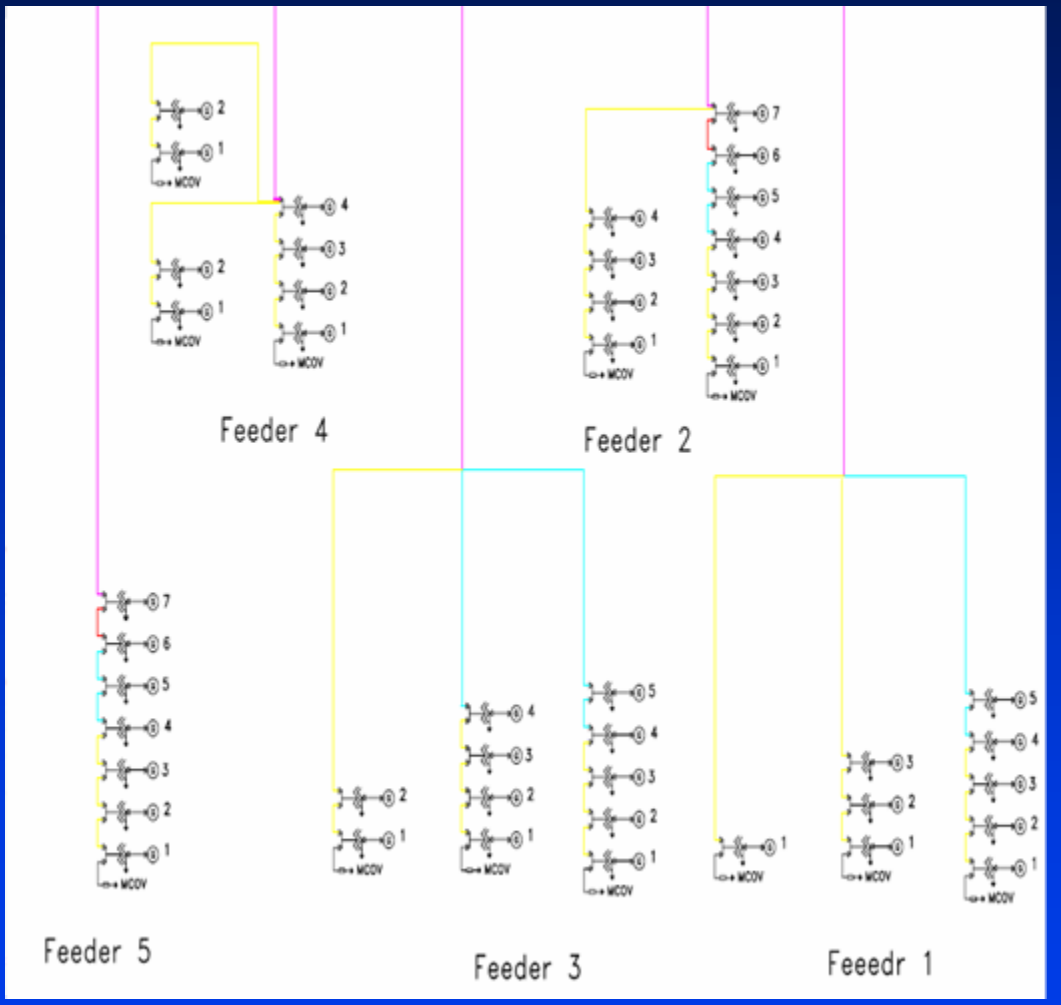
Manufacturing in the United States

- In 2006…
  - Five wind turbine manufactures open U.S. manufacturing and assembly plants
    - Clipper Windpower
    - Gamesa
    - Siemens
    - Suzlon
    - GE
  - TECO/Westinghouse announced an agreement with DeWind to manufacturer wind turbines in Texas
- In 2007…
  - Acciona Energia of Spain announced to build a new wind turbine manufacturing in Iowa
  - VESTAS plans to open a facility in Colorado

Electrical Engineering and Construction

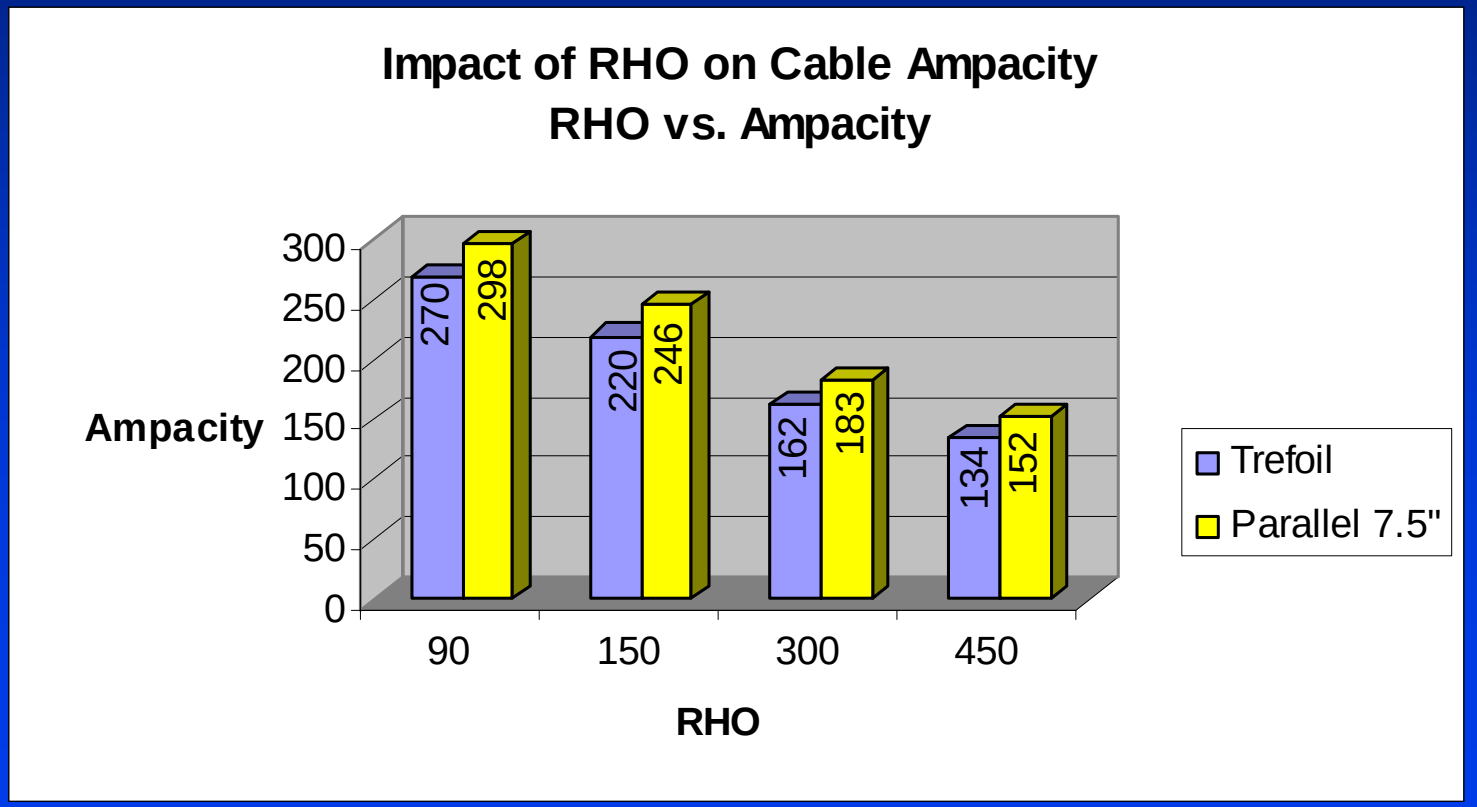
A Collector System

- Provides a network to harness output of each wind turbine generator
- Delivers the output to a substation for interconnection to the grid
- Collector Circuits
  - 35kV Primary Circuits
  - 600V Secondary Circuits



Studies and Analysis

- Soil Rho significantly impacts cable ampacity
  - 4/0 AL Cable Direct Buried, 90˚C



Studies and Analysis

- Soil Rho
  - Soils Map
  - Sample Locations
  - Site Excavation
  - Measurements
  - Results
  - Report

Geotechnical Sampling Locations

GEOTHERM INC.
email: geotherm@geotherm.net

P.O. Box: 742
Aurora, Ontario
CANADA
L4G 4J9
Tel: 905-727-6448
Fax: 905-727-4325

March 9, 2007

S&C Electric Company
Power Systems Services Division - WEG
6601 North Ridge Boulevard
Chicago, IL 60626-3904
Attn: Ted Nicolai, Project Manager

Re: Thermal Analysis of Native Soil Samples
Gulf Wind Project, Kenedy County, Texas. Your PO # 266289

We are pleased to submit this test report of thermal dryout characterization conducted on the six (6) native soil samples from the referenced project. These were disturbed bulk samples taken in Ziploc bags and identified with the Turbine location.

Test Procedure and Equipment:
Per our discussion and your request, each sample was compacted at the respective "natural moisture" content and at 90% dry density given in the ***Wind Connect Alliant Energy*** test report of February 2, 2007. A series of thermal resistivity measurements were made in stages; with the moisture content ranging from the "natural" to the totally dry condition. The tests were conducted in accordance with the IEEE Standard using our Thermal Property Analyzer and laboratory type thermal probes. The thermal dryout curves are presented in ***Figures 1and 2***.

Sample ID, Description, Moisture Content, Dry Density and Thermal Resistivity

Turbine #33
Brown fine silty sand
Thermal resistivity at "natural" moisture content of 19% = 54 °C-cm/W
Thermal resistivity in dry condition (0% moisture content) = 325 °C-cm/W
Dry density = 92 lb/ft^3

Turbine #54
Brown slightly silty fine sand
Thermal resistivity at "natural" moisture content of 20% = 58 °C-cm/W
Thermal resistivity in dry condition (0% moisture content) = 345 °C-cm/W
Dry density = 90 lb/ft^3

COOL SOLUTIONS FOR UNDERGROUND POWER CABLES
THERMAL SURVEYS, CORRECTIVE BACKFILLS & INSTRUMENTATION
Serving the electric power industry since 1978

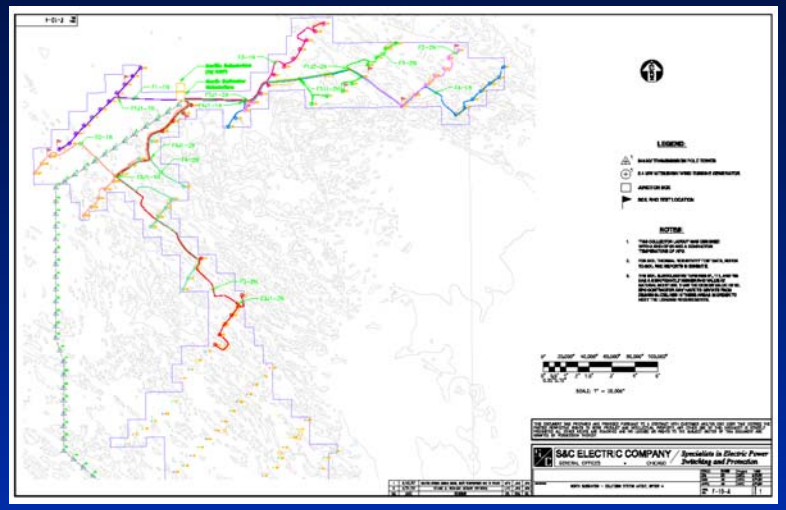
Studies and Analysis

- Cable Conductor Selection
  - Typically Aluminum – Less Expensive
  - Largest Conductor used is typically 1000 kcmil
  - Limit unused cable, stocking of spare parts, etc.

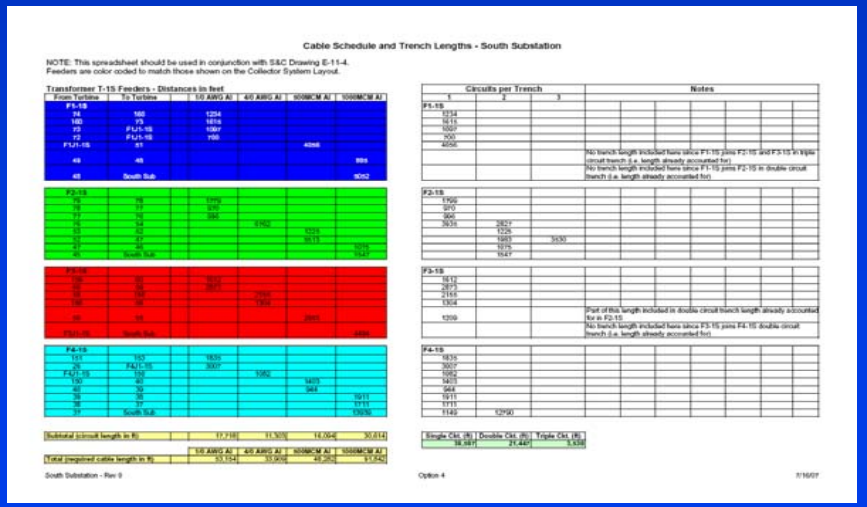
- Underground Cable Parameters
  - Conductor Temperature
  - Insulation Level
  - Insulation Type
  - Short Circuit Rating

Studies and Analysis

- Designing the Collector System
  - Relative location of turbines
  - Turbines per Feeder
  - Cable Selection
  - Sectionalizing/Switching Points
    - Consider fault locating
  - Short circuit and coordination
  - Grounding
  - Surge protection



$$\frac{MW*1000}{\sqrt{3}*kV*pf} = Amps$$



Wind Plant Studies

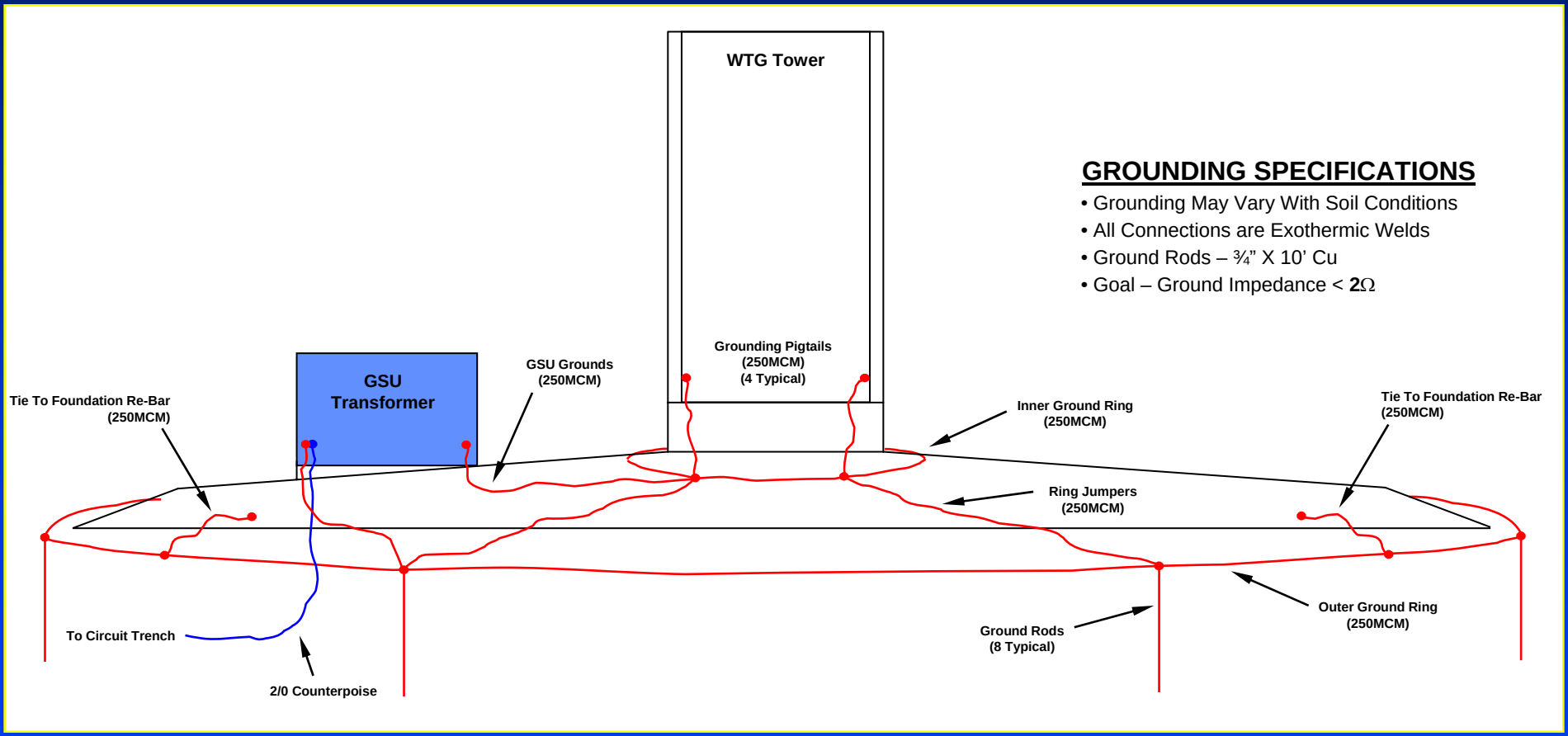
	Purpose	Analysis
Feasibility Study	Identifies limits to connect to existing grid	Power Flow, Linear Transfer, Deliverability, Contingencies
System Impact Study	System upgrades to resolve limits from above	Short Circuit, Transient Stability, Dynamic Stability
Harmonics	Understand circuit components affecting resonance	Max / min system MVA, transformers and capacitors
Control Interactions	Idenitfy wind turbine controls, fast-capacitor switching logic volt/VAR regulation, fault response	Time domain analysis with scheduled and unscheduled outages internal and external to wind plant
Transient and Temporary Overvoltage	Verify arrester capability, relaying and control responses	Model scenarios with switched capacitors and inverter devices
Interconnection Study	Validate system operations	Load flow, short circuit dynamic stability, protective device coordination, insulation coordination, cable ampacity

FERC Order Impact on Wind Integration

- Low voltage ride-through (LVRT)
  - Generator stays on line during a 3 phase fault with normal fault clearing (~4 to 9 cycles) and subsequent post fault voltage recovery to prefault voltage unless clearing the fault disconnects the generator
- Voltage support and dynamic reactive power
  - Provide power factor of +/- .95 with dynamic voltage support
- New transmission and transmission reservation
- Meet NERC reliability rules
- SCADA as agreed with transmission provider

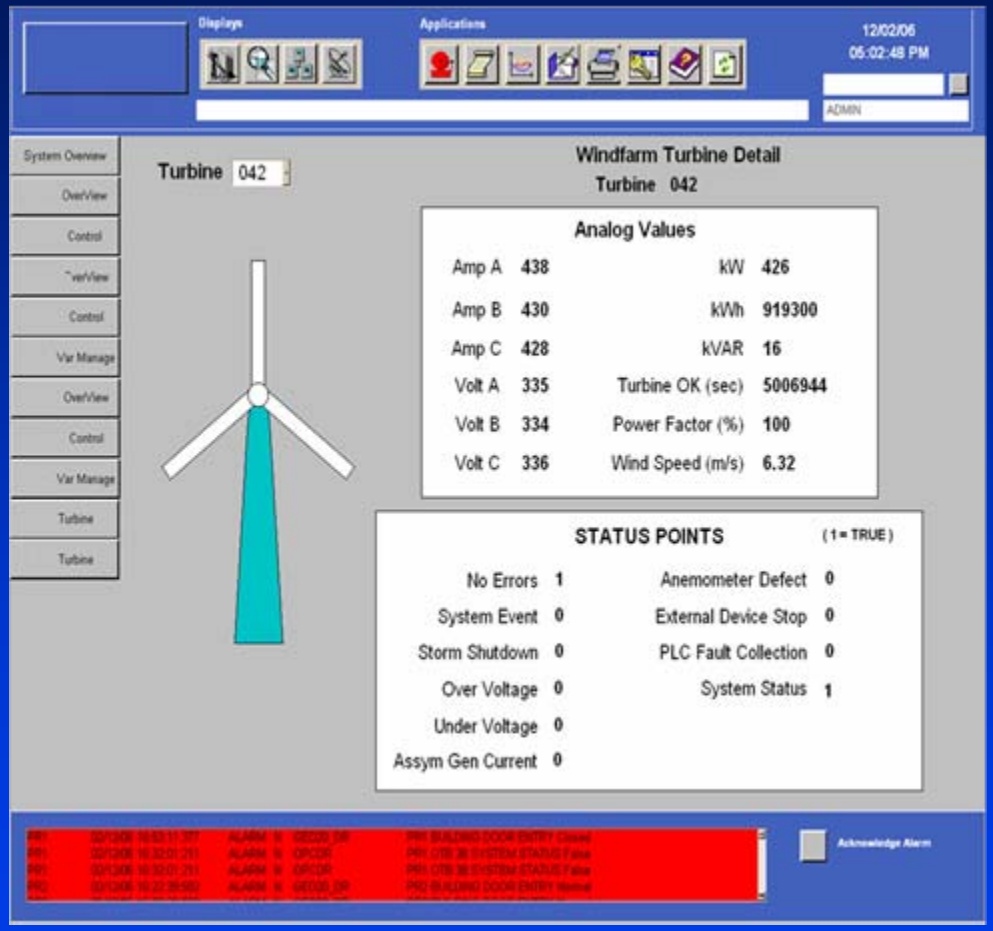
Construction & Installation Requirements

- *WTG Foundations – T/Spread Footing Grounding*



Other Design Considerations

- SCADA Systems
  - Design Considerations
    - Circuit Length
    - Number of Turbines on a Circuit
    - Fiber Type
  - Turbine Control
    - On/Off line, set-point commands (inputs)
    - Measurements
  - Wind Plant Control
    - Controls voltage or power factor and plant output at point of interconnect
    - Sends commands to individual turbines



Construction & Installation Requirements

- *Collector Circuits – 35kV Primary Circuits*
  - Trench Excavation

Construction & Installation Requirements

- *Collector Circuits – 600V Secondary Circuits*
  - Material Installation
    - GSU Vault

Construction & Installation Requirements

- *Collector Circuits – 600V Secondary Circuits*
  - Material Installation
    - GSU Vault
    - GSU

Construction & Installation Requirements

- *Collector Circuits – 600V Secondary Circuits*
  - Material Installation
    - GSU Vault
    - GSU
    - Tower Wiring

Construction & Installation

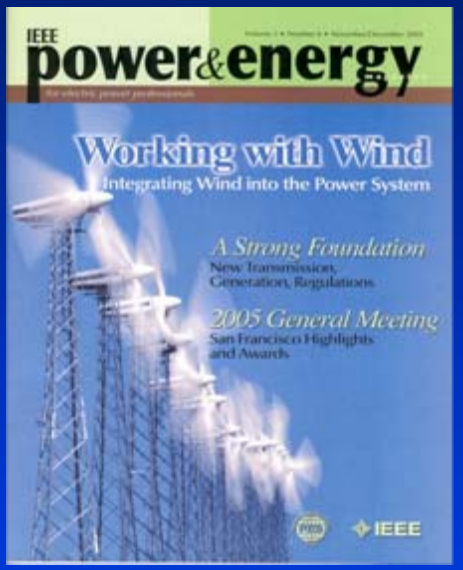
- *Collector Circuits – 35kV Feeder Switching*
  - Circuit-Breakers
  - Switchgear

Wind Power Coming of Age

- IEEE PES Wind Power Coordinating Committee (WPCC) established 2005
- IEEE PES *Power & Energy* magazine
  - Nov-Dec 2005
  - Nov-Dec 2007
- IEEE/NERC/AWEA/UWIG

  Wind Policy Symposium:

  April 2006



- WPCC Sub-committee on collector system design to address emerging application issues – for example
  - harmonic voltage distortion
  - protection of delta-delta collector circuits with grounding transformers

Conclusions

- Wind is realizing explosive growth
- The knowledge base is growing with the installed capacity
- Technology, policy and standards are advancing
- Standards for models and interconnections are evolving
- Projects are complex from a commercial, technical and project management perspective
- Large wind plants are evolving to look conventional generation
- IEEE PES is addressing technical challenges
  - A significant contributor
  - Expanding presence

For More Information Contact:

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