

Wind Plant Modeling for Bulk System Planning

North American Wind Energy Academy 2013 Symposium

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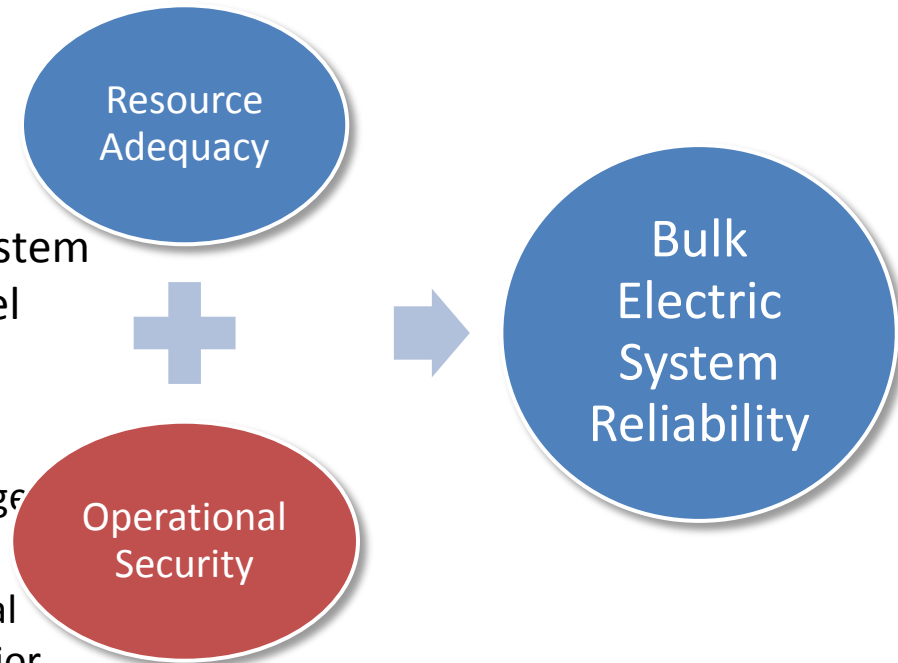
Robert Zavadil
Executive Vice President
620 Mabry Hood Road, Suite 300
Knoxville, Tennessee 37932
Tel: (865) 218-4600 ex. 6149
bobz@enernex.com
www.enernex.com

Overview

- ❑ Why models?
- ❑ Wind generation modeling challenges
- ❑ Progress and status
- ❑ Is it real?

Role of Models in Bulk Power System Planning

- ❑ Proper computer and simulation models are indispensable for maintaining grid reliability
 - Identify impact of new generator, transmission equipment additions
 - Perform planning studies to ensure system reliability at the local and regional level
- ❑ Modeling focus for grid studies
 - Steady-state: power flow for voltage and reactive compensation assessment, contingency evaluation
 - Dynamic: behavior of system and individual elements during and immediately after major system disruptions (e.g., short-circuits, loss of major generators, etc.)
- ❑ Model requirements addressed in existing (and future) NERC standards

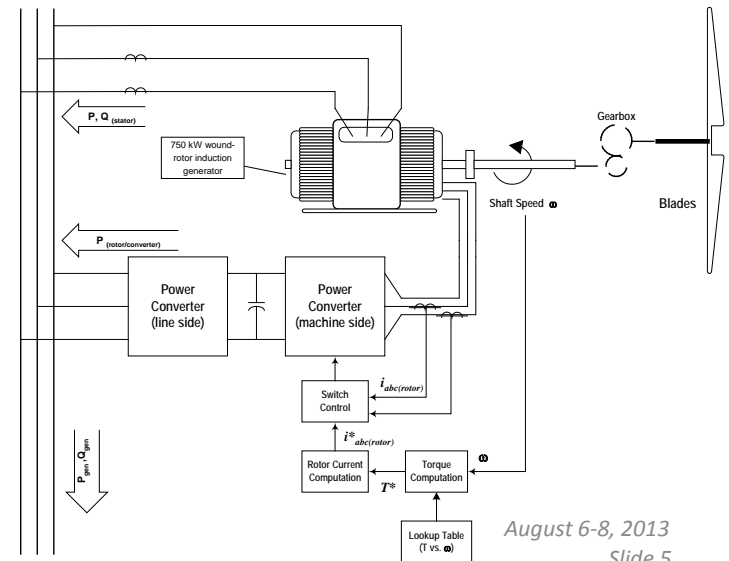
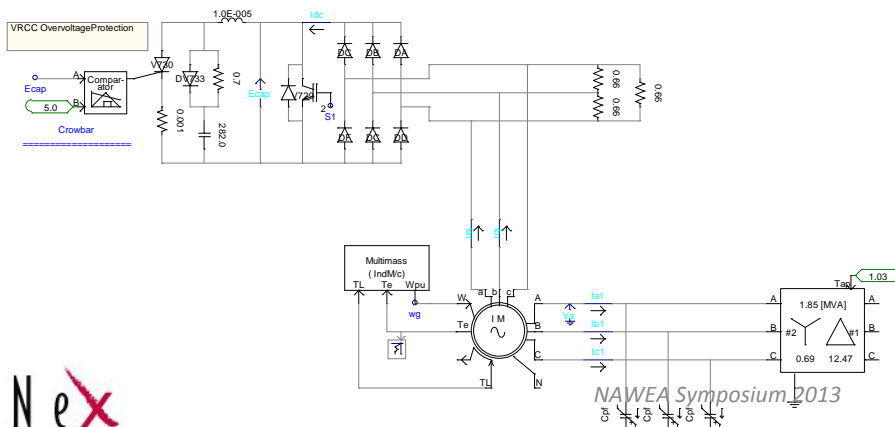
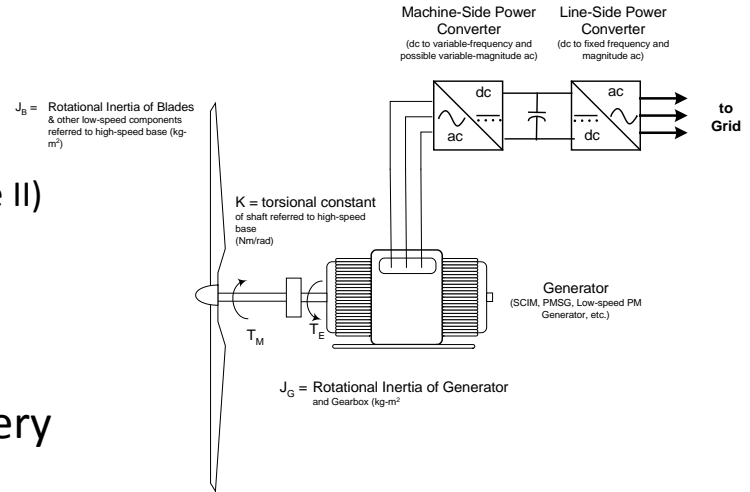


Bulk Wind Generation is a “player”

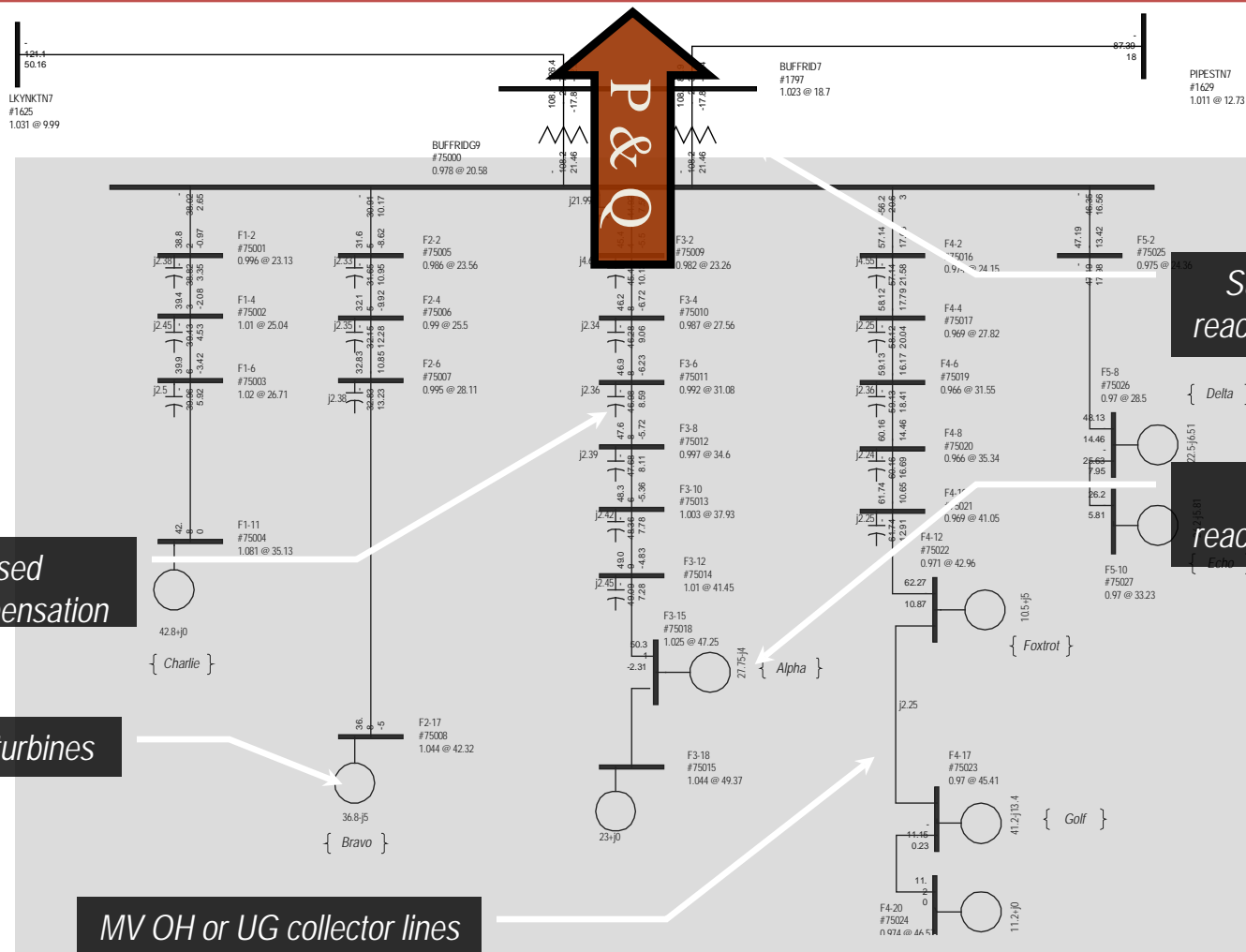
- ❑ Wind generation is no longer “invisible”
 - Requirements for models have not been strictly enforced by transmission providers
 - Engineering judgment has played large role in previous studies
- ❑ Present approach is incompatible with the current system modeling practice
 - Many vendors have characterized their equipment in appropriate models
 - Issues
 - » Models can be confusing or cumbersome: features, versions, etc.
 - » Considered proprietary; made available after signing NDAs
- ❑ Cannot be maintained in base cases once plant is built
 - Base cases used for planning going forward
 - NDA riders not feasible under structures for model development, maintenance, and distribution

Energy Conversion Technology for Wind Generation

- ❑ Novel relative to conventional generation equipment
 - Conventional induction machines (Type I)
 - Induction machines w/ rotor resistance control (Type II)
 - Doubly-fed asynchronous machines (Type III)
 - Full power conversion – static interface (Type IV)
- ❑ Wind plants have dozens – hundreds of small generators; conventional plants have a few very large generators
- ❑ Conventional generation technology well known; modeling efforts ongoing for 75+ years!



Wind Plant Components



Plant-based reactive compensation

Groups of wind turbines

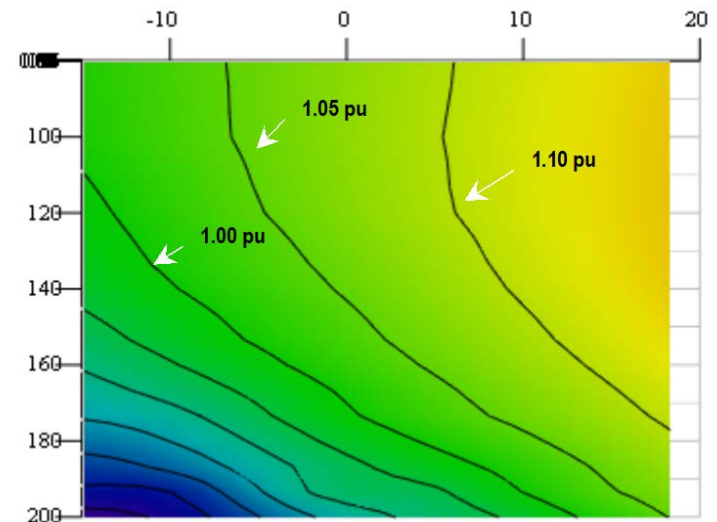
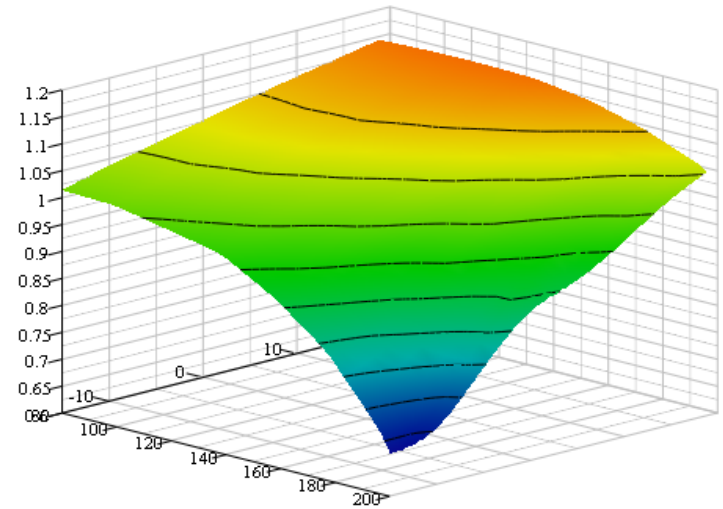
MV OH or UG collector lines

Substation-based reactive compensation

Turbine-based reactive compensation

Interconnection Challenges

- ❑ Remote facilities
 - Typically interconnection to weak transmission network
 - Transmission capacity questions
- ❑ Reactive power dispatch
 - Dynamic character of wind generation
 - Coordination of reactive power control
- ❑ Interconnection requirements are evolving
 - Were typically very simple
 - Have evolved to voltage control, dynamic reactive power management
- ❑ Wind plants should behave like conventional plants, except for real power control



Status

- ❑ Wind turbine and plant modeling remains at top of power industry needs list
- ❑ Landscape is much different than it was 5 years ago
 - Many parallel activities
 - Increased and widespread interest
 - The clock is now ticking (NERC)...
- ❑ Much progress made since over past five years
 - Individual efforts (turbine vendors, TSPs)
 - WECC initiative w/ voluntary contributions
 - IEC TC 88 WG 27
- ❑ Progress needs to be accelerated as firm deadlines are now probable

NERC IVGTF Phase II Task 1.1 - Scope

- ❑ From recommendations of Phase I report
- ❑ Focus on modeling for interconnection and other bulk system studies
- ❑ Phase II recommendations complete

Item #	Proposed Improvement	Abstract	Lead	Deliverables	Milestones
1.1	Standard, valid, generic, non-confidential, and public power flow and stability models (variable generation) are needed and must be developed, enabling planners to maintain bulk power system reliability	Valid, generic, non-confidential, and public standard power flow and stability (positive-sequence) models for variable generation technologies are needed. Such models should be readily validated and publicly available to power utilities and all other industry stakeholders. Model parameters should be provided by variable generation manufacturers and a common model validation standard across all technologies should be adopted. The NERC Planning Committee should undertake a review of the appropriate Modeling, Data and Analysis (MOD) Standards to ensure high levels of variable generation can be simulated. Feedback to the group working on NERC Standards' Project 2007-09 will be provided.	<i>Ad Hoc</i> group: Members from IVGTF - Planning	Make recommendations and identify changes needed to NERC's MOD Standards	<ul style="list-style-type: none"> • Draft report ready by December 2009 PC meeting • Final report sent with recommendations to PC for endorsement in February 2010 • Develop SAR with Standards Committee if required.

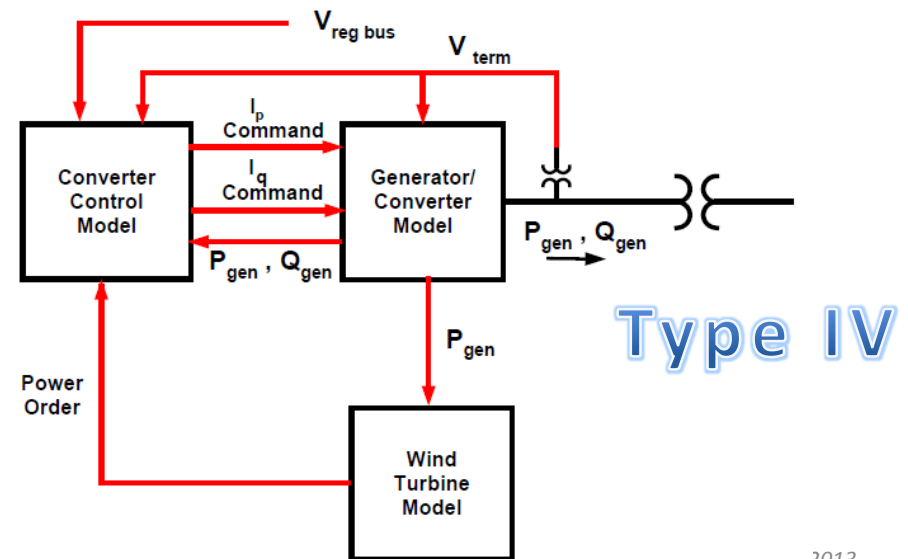
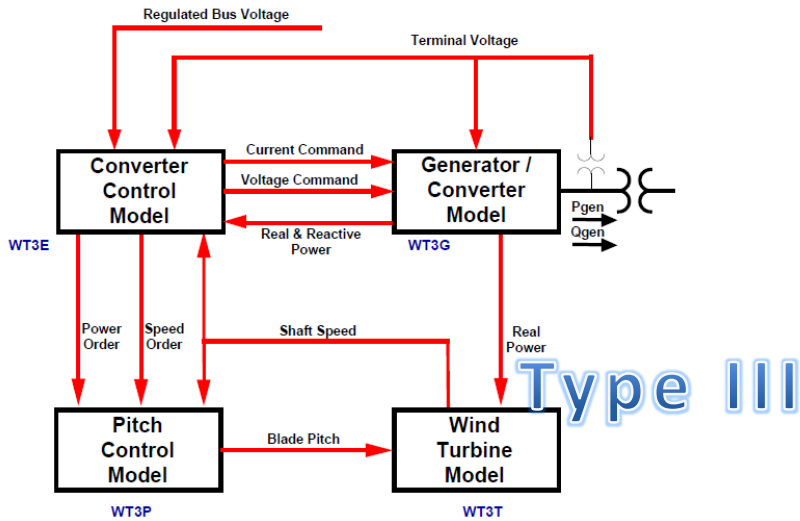
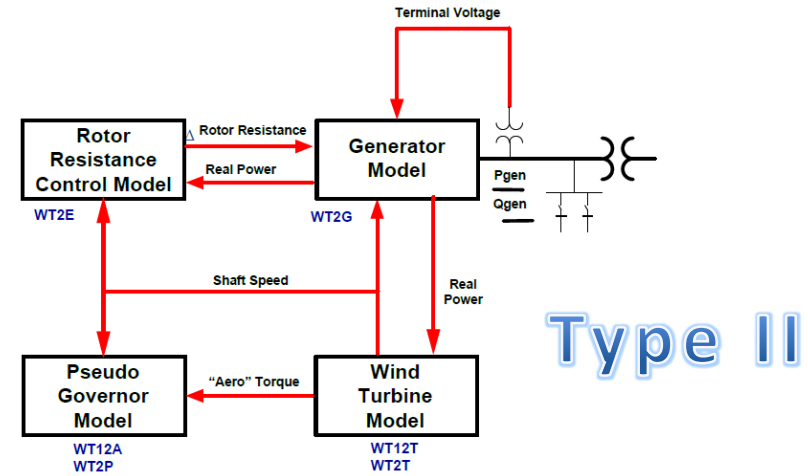
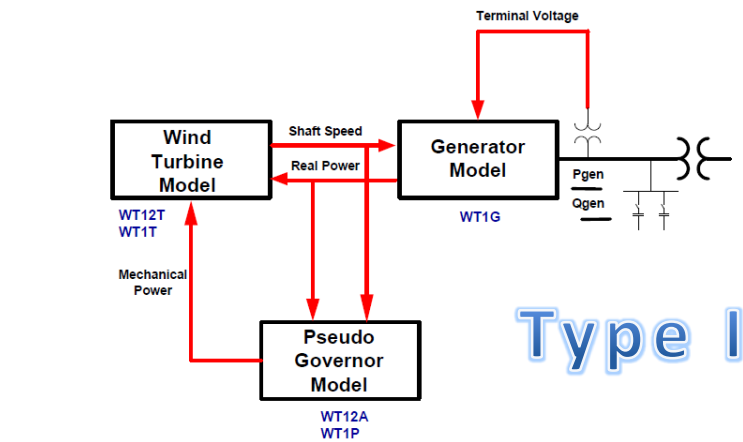
UWIG Generic Modeling Initiative

- ❑ Build on efforts initiated by WECC in 2005 to develop generic models for wind turbines and wind plants
- ❑ Utility Wind Integration Group / EnerNex project team
- ❑ DOE FOA 68
 - “20% Wind by 2030”
 - Topic 4A: Utility Wind Energy Integration
- ❑ Commitment of support from turbine vendors, National Laboratories, NERC, IEEE, RREs
- ❑ Work began 1Q '10
- ❑ **Overall goal is to accelerate model development process for wind generation**

Applicability of Generic Models

- ❑ Conventional generation equipment represented from “library” of standard elements
- ❑ Similarly, generic wind turbine models are intended for transmission planning and interconnection studies
 - Application is simulation of system stability (voltage & angle) in positive-sequence environment, following faults and/or switching of transmission, generation, load, etc.
 - Focus on grid disturbances, not wind disturbances
 - Typical simulations are 10-30 sec duration
- ❑ Some simplification is required, consistent with power system modeling practice
 - Avoid confidentiality issues and avoid requirements for unreasonably short integration time steps
 - Models still need to be validated and useful

Generic Models – V1

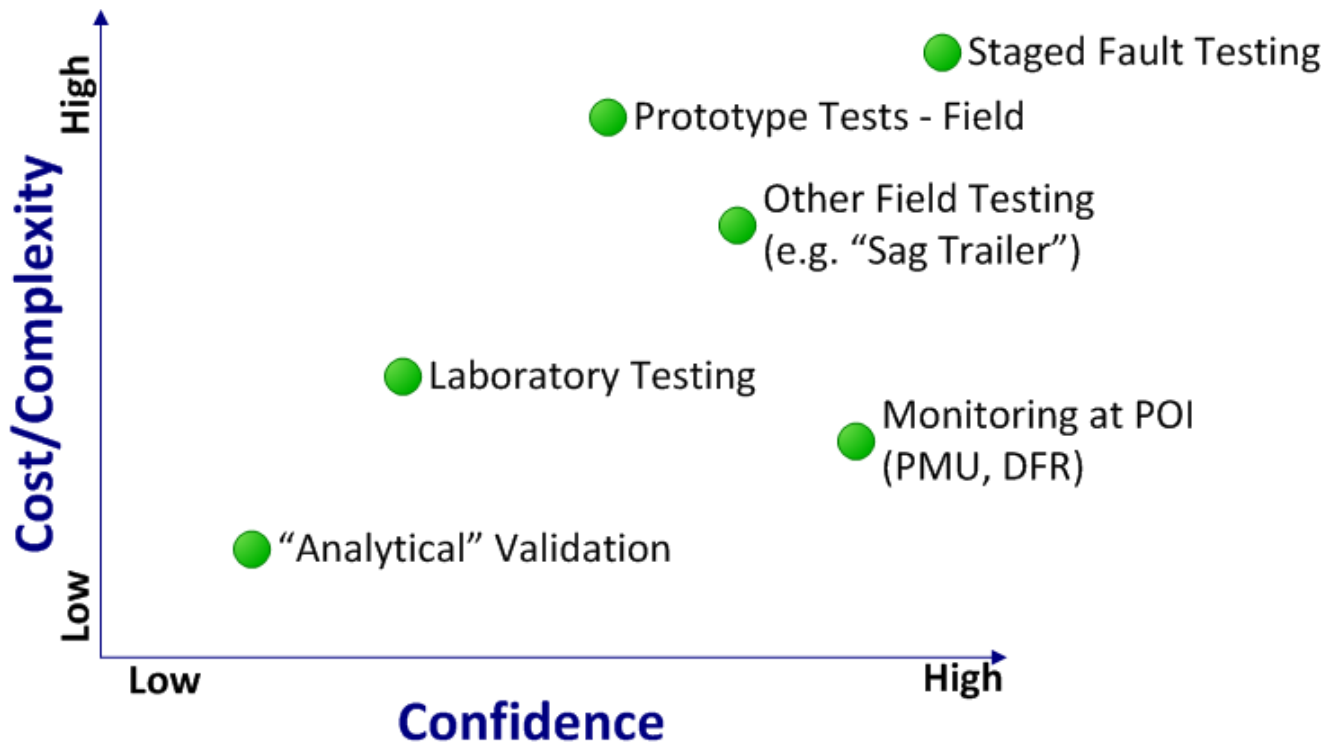


Context

- ❑ Emphasis is on very specific models for bulk electric system impact studies, not “models” generally
- ❑ Behavior of turbines/plant under defined range conditions
 - Large-signal, short-duration variations of voltage and/or frequency
 - BES origin, not wind-driven
- ❑ Wind plants vs. conventional generators
 - Conventional generators -> synch. Machine + exciter + governor
 - Wind plants comprised of many (exotic) machines, and lots of other stuff
 - “Plant” vs. “Generator” validation

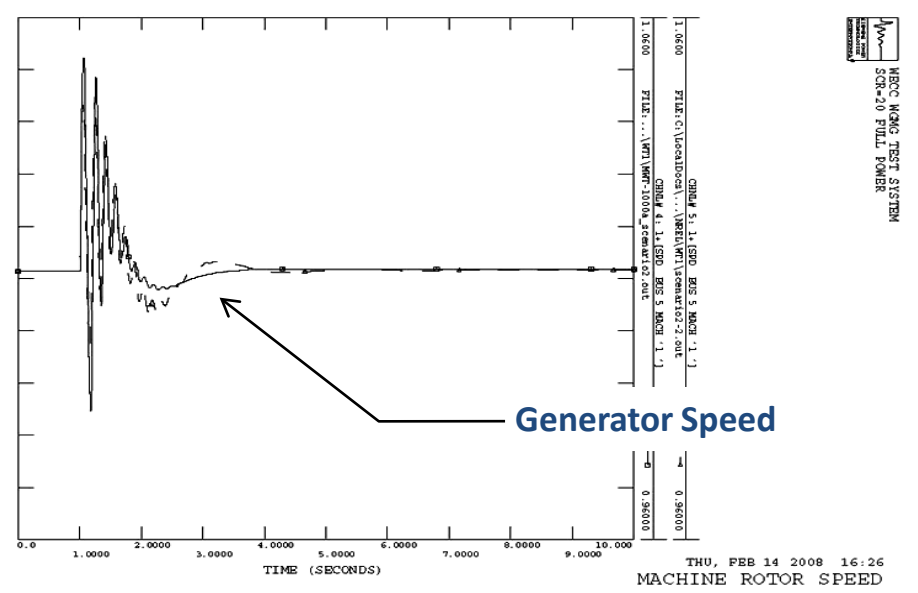
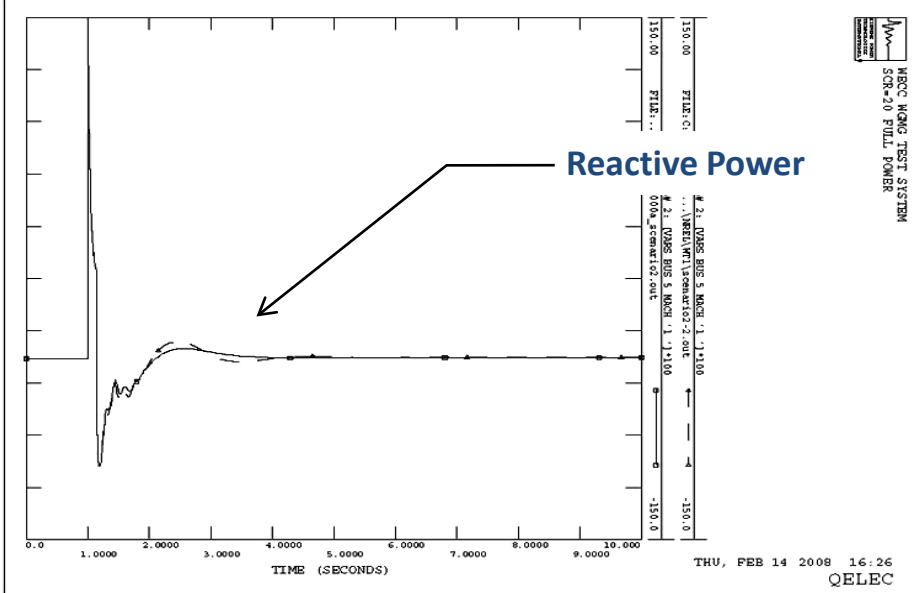
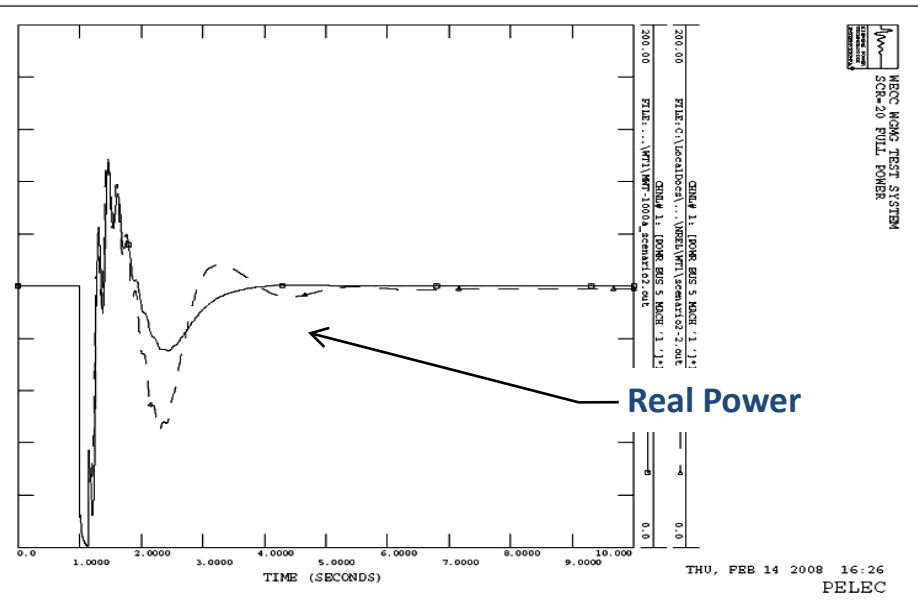
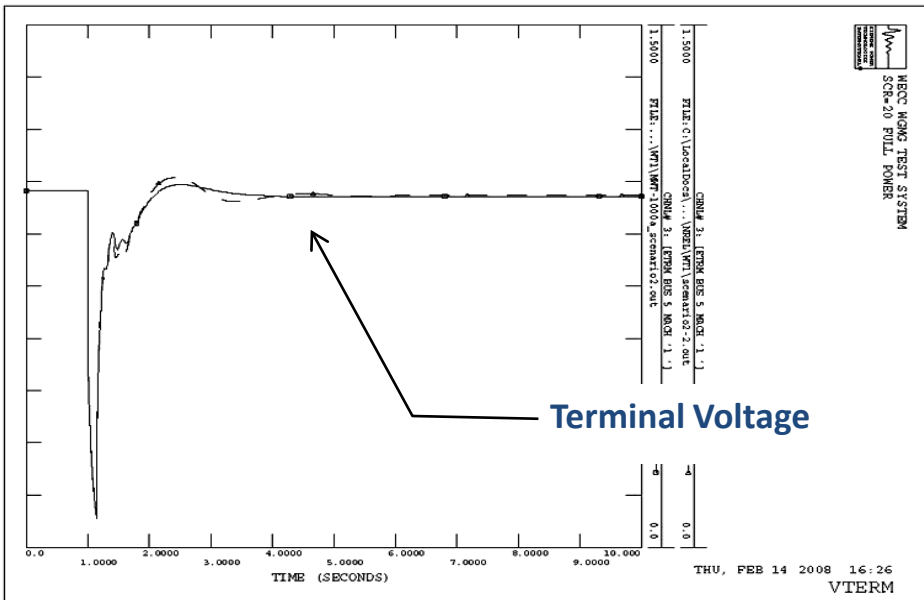
Approaches for Model Validation

- ❑ Various methods can and have been used
- ❑ All have advantages and disadvantages



PMU Data appears ideal for validation...

- ❑ First-principle quantities (i.e. voltage, grid injection current phasors) at resolution cycle-by-cycle resolution
 - Response of wind plant to large-signal disturbances on grid
 - » Voltage (short-circuits)
 - » Frequency excursions
 - PMU resolution is consistent with bandwidth of dynamic simulations in major bulk system analysis tools (PSS/E, PSLF)
- ❑ Monitoring at wind plant interconnection to BES would provide sufficient data for characterizing performance
 - Voltages and currents
 - Other important quantities can be derived



Dashed: Vendor-specific detailed model. Solid: WT1 model
 EnerNex

...but

- ❑ A specific event may be hard to replicate via simulation
 - Plant model complexities
 - Initial conditions/system state
 - Origin and nature of system disturbance
- ❑ Actual events will be asymmetrical
 - PSS/E, PSLF models are positive sequence only
 - Unbalanced events model very approximately
 - 3-phase faults are extremely rare
- ❑ Events are infrequent
 - With just a few monitored locations, appropriate data for validate may be long in coming
 - Can be partially remedied by monitoring at many locations
- ❑ Large number of commercial turbines to validate

Summary

- ❑ PMUs will likely become a prime source of data for validation of all power system models
- ❑ Validation seems straightforward, but:
 - Over 500 individual plants in the current fleet – validation for each one?
 - Regional Entity, transmission planning staff already busy
- ❑ And, what will NERC and/or the Regional Entities require for validation?