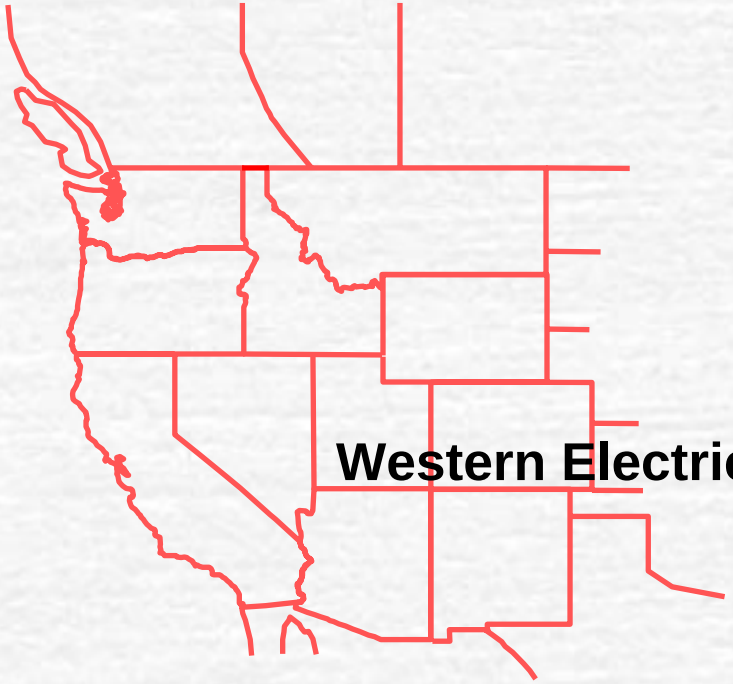

Western Electricity Coordinating Council

Generic Wind Turbine-Generator Models

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Time For A Change

- Wind generation is no longer “invisible”
  - WECC has 3.7 GW of wind generation capacity installed
  - Some areas are experiencing high saturation levels
  - Significant expansion expected in the near future
- Adequate planning models are indispensable to design for and maintain power system reliability
  - Define interconnection requirements for new wind power plants based on established methods and criteria
  - Include the effects of installed wind power plants in on-going system planning studies

Time For A Change

- The Status Quo is not acceptable
  - Thus far, numerous, proprietary, black-box and one-of-a-kind models have been produced with little or no input from users
  - As a result, models are generally incompatible across simulation platforms and unavailable in some cases); they are also difficult to validate, access, use and maintain
- Pressure to move toward standard models has reached a critical level in the industry
  - Need leadership with vision to achieve convergence

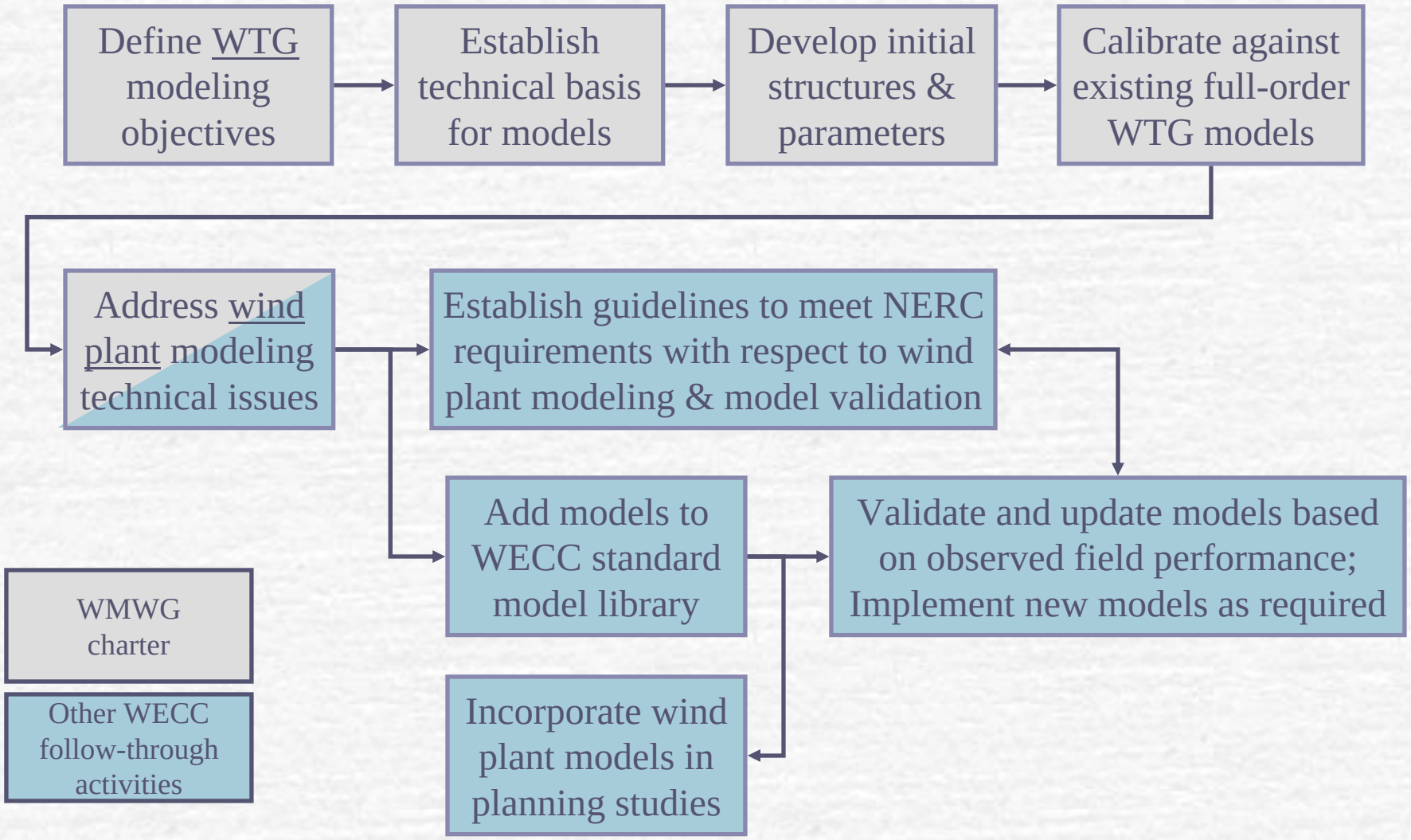
~~Yet Another~~ A Different Wind Modeling Effort

- Wind Generator Modeling Group
  - Convened by Modeling & Validation Work Group (MVWG) in July, 2005, working under the auspices of WECC
  - Broad industry participation and buy-in
    - Program developers - GE PSLF, Siemens PSS/E
    - Program users - WECC and Europe
    - Key organizations - AWEA, NREL, UWIG; coordination with IEEE and CIGRE
    - Equipment vendors
- Not just a WECC activity

Mission Statement

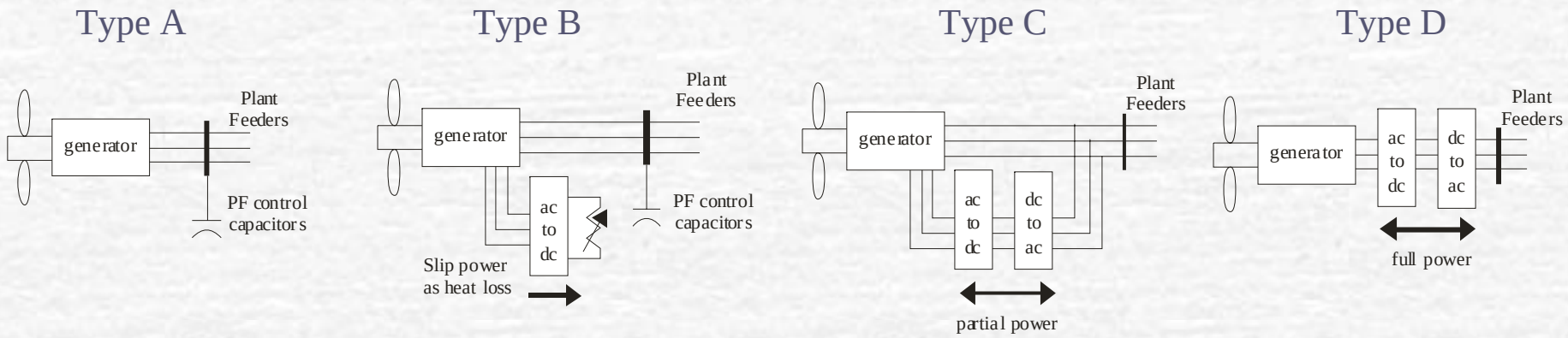
- WGMG will work to achieve the following goals:
  - Develop a set of generic (non-vendor specific), non-proprietary, positive-sequence power flow and dynamic models suitable for representation of all commercial, utility-scale WTG technologies, and
  - Develop a set of best practices to represent wind plants using generic models as basic building blocks
- Coordinate directly with wind manufacturers and other stakeholder groups outside WECC

Model Development Process



Proposed Standard Models

- Based on characteristics of grid interface
  - Type A – conventional induction generator
  - Type B – wound rotor induction generator with variable rotor resistance
  - Type C – doubly-fed induction generator
  - Type D – full converter interface



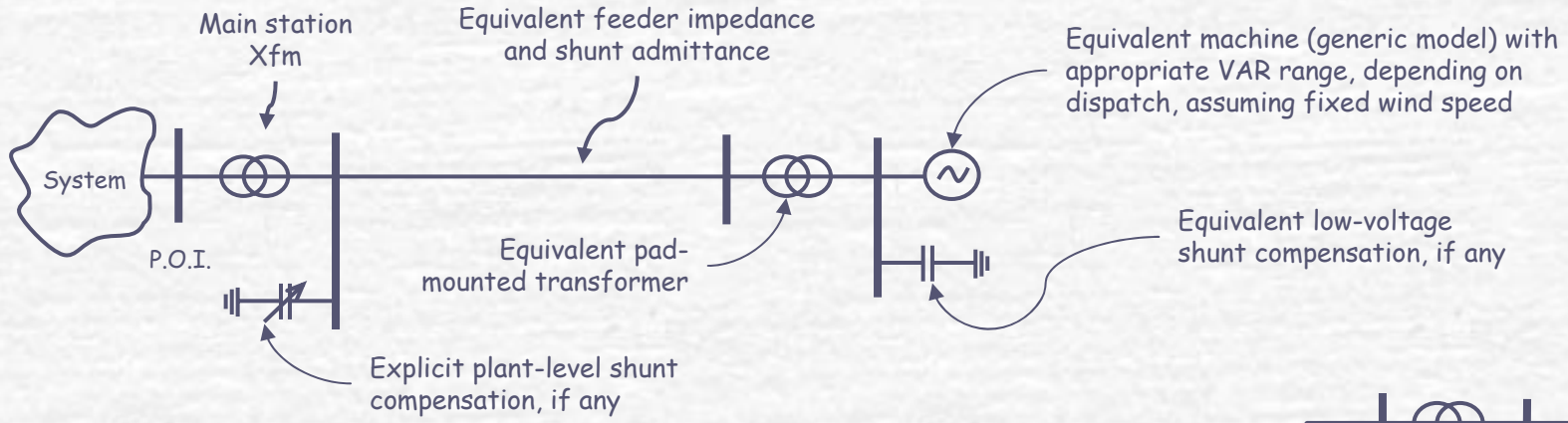
Technical Challenges

- Grid disturbances versus wind disturbances
  - Performance in response to grid disturbances can be modeled reasonably well using generic models
  - Performance in response to wind disturbances could introduce complications – but note that this is less importance in a transmission planning context
- Wind generator model versus wind plant model
  - Wind plant “equivalencing” is needed to reduce data requirements and computational burden

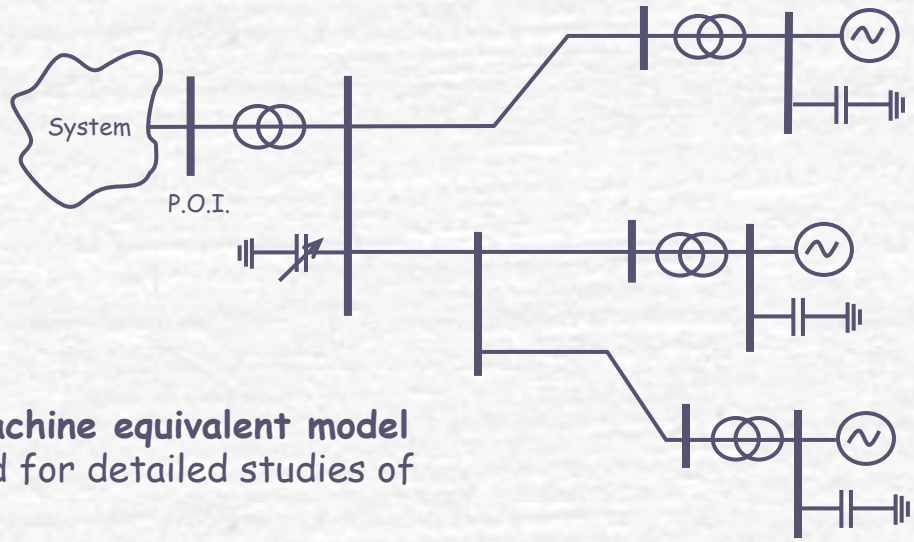
WGMG will focus on generic WTG models suitable for simulation of grid disturbances such a faults.

Technical Challenges

- Single and multiple generator “equivalencing”



A single-machine equivalent model should be good for general-purpose studies of regional and local interest.



A multiple-machine equivalent model may be needed for detailed studies of local interest.

Technical Challenges

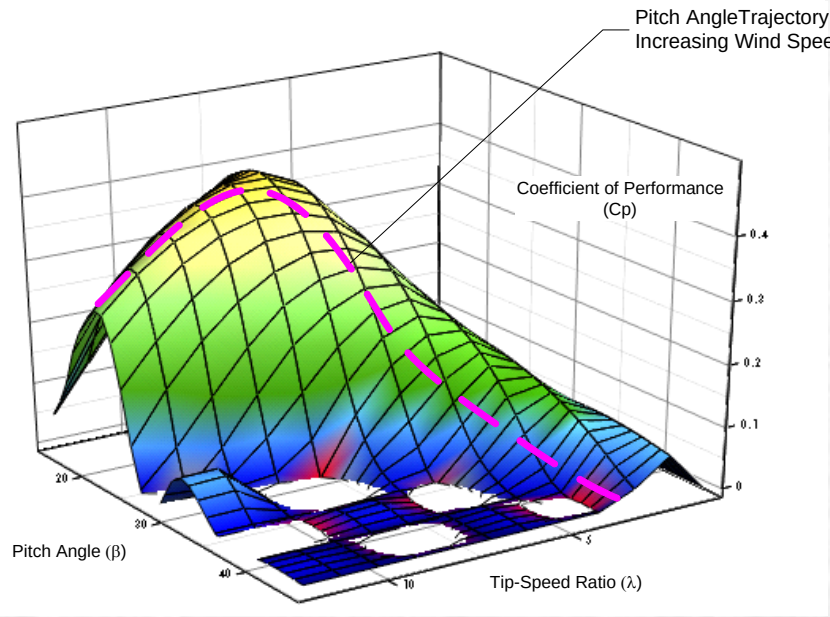
- Simplification of aerodynamic characteristics
  - The mechanical power (*Pmech*) applied to the generator is a function of the performance factor (*Cp*)

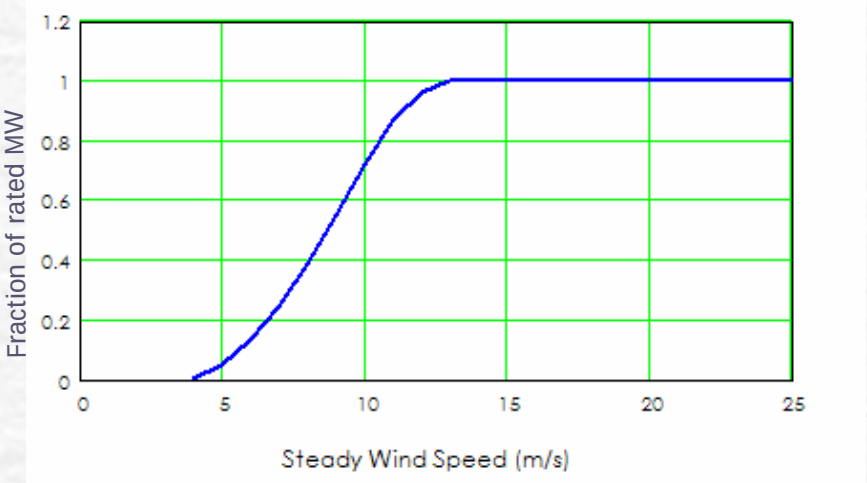
$$Pmech = \tfrac{1}{2} \times (\text{air density}) \times (\text{swept area}) \times Cp \times (\text{wind speed})^3$$

  - *Cp* is a function of blade pitch and tip-speed ratio (or just rotor speed, if wind speed is assumed constant)
  - During a typical dynamic simulation, blade pitch and tip speed ratio vary, thus *Cp* and *Pmech* will also vary
  - *Cp* is modeled using a look-up table or *Cp* matrix specific to each WTG provided by the manufacturer usually on a confidentiality basis

Technical Challenges

- Example
  - Typical *Cp* curve (left) for a fixed-speed WTG (Type 1). The dashed magenta line shows operating points that correspond to the steady-state power curve (right)
  - Can a simplified model that captures the important performance characteristics of this type of WTG?





Technical Challenges

- A fundamental assumption is that a simplified representation of the aerodynamics is required to develop generic, non-proprietary models
- Initial investigation showed encouraging results
  - For variable speed WTGs, the relationship between *Pmech* and pitch angle is nearly linear over a wide range of operating conditions
  - For fixed speed WTGs, the relationship between *Cp* and pitch angle is nearly linear over a wide range of operating conditions
  - WGMG is currently evaluating approaches to implement these observations in a dynamic simulation environment

Related WECC Activities

- WECC Wind Generation Task Force (WGTF)
  - Disseminate of technical information
  - Develop wind generation representation in technical studies
  - Assess conformance to WECC reliability standards, policies and frequency requirements
  - Recommend enhancements to existing or propose new WECC standards
  - Recommend study procedures for performing wind interconnection studies

Related WECC Activities

- WECC proposed generator testing policy
  - Wind plants 20 MVA or larger are expected to comply with WECC's generator testing policy
    - Submit data for model approved for use in WECC
    - Update models after material equipment changes, observed discrepancy between model and actual performance
    - Perform model validation at least every 5 years
  - Modeling requirements will be based on the results of the WGMG and WGTF efforts
  - Testing requirements will be very basic since there is limited industry experience in this area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