Wind Turbine Models in PowerWorld Simulator

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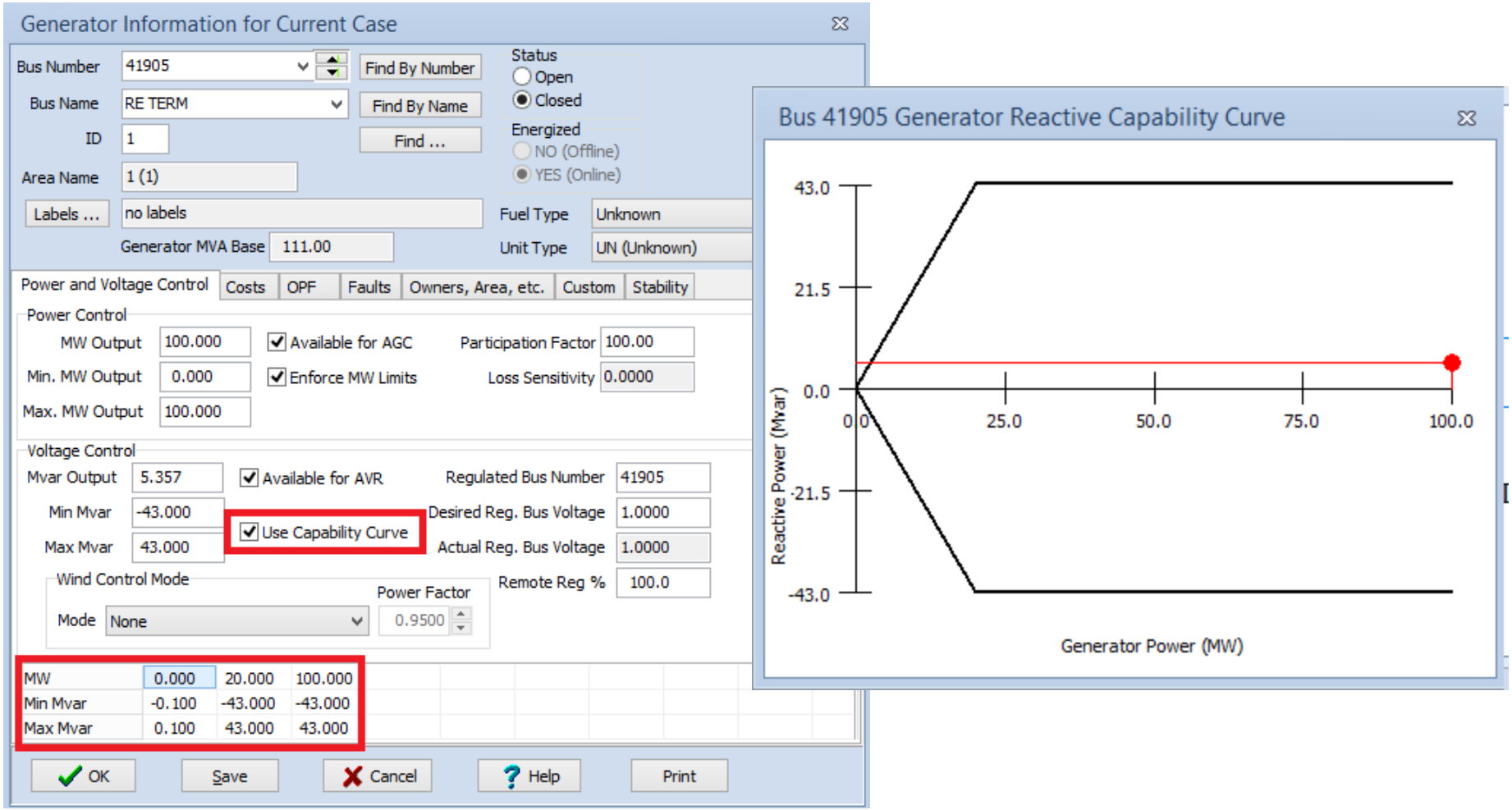
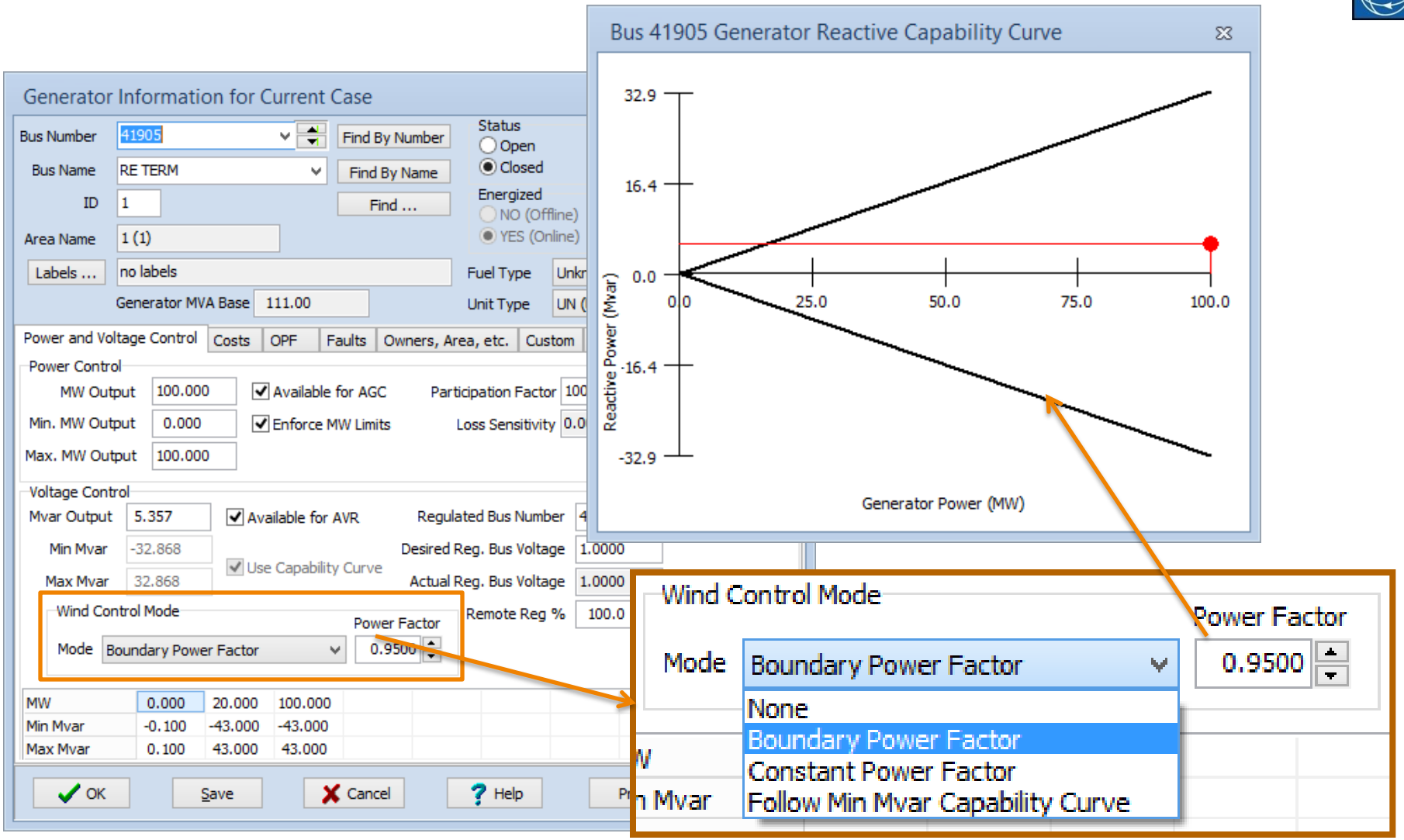
Power Flow Models of Renewable Generation Plants

- Abe presented this morning
  - Build out the equivalent of the collector system
  - Represent the plant as a generator
- For a software user, the only difference is the reactive capability curve
  - Users can enter a piecewise linear curve
  - Users can also specify a “wind control mode”
    - Boundary control
    - Constant power factor

Mvar Capability Curves: Piecewise Linear Curve



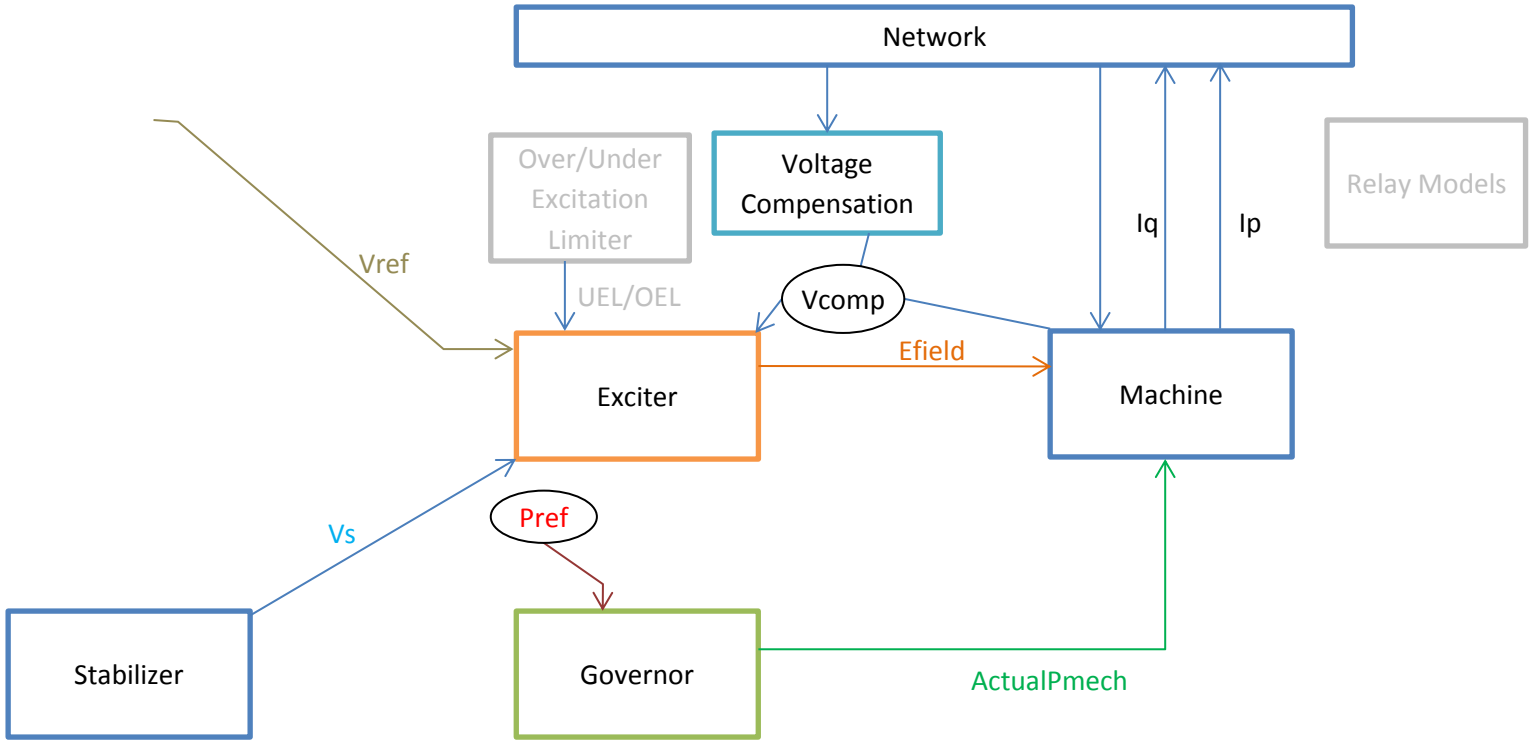
Mvar Capability Curves: Wind Control Mode = Boundary



Modular Approach to Generator Modeling in Transient Stability

- Industry has always used a modular approach for generator models
  - Machine
  - Exciter
  - Governor
  - Stabilizer
  - Under Excitation Limiter
  - Over Excitation Limiter
  - Relay Model
    - GP1, LHFRT, LHVRT
  - Compensator Model
    - Often is part of the machine model, but can also be a separate model
    - The old BPA IPF program models included this in the Exciter model

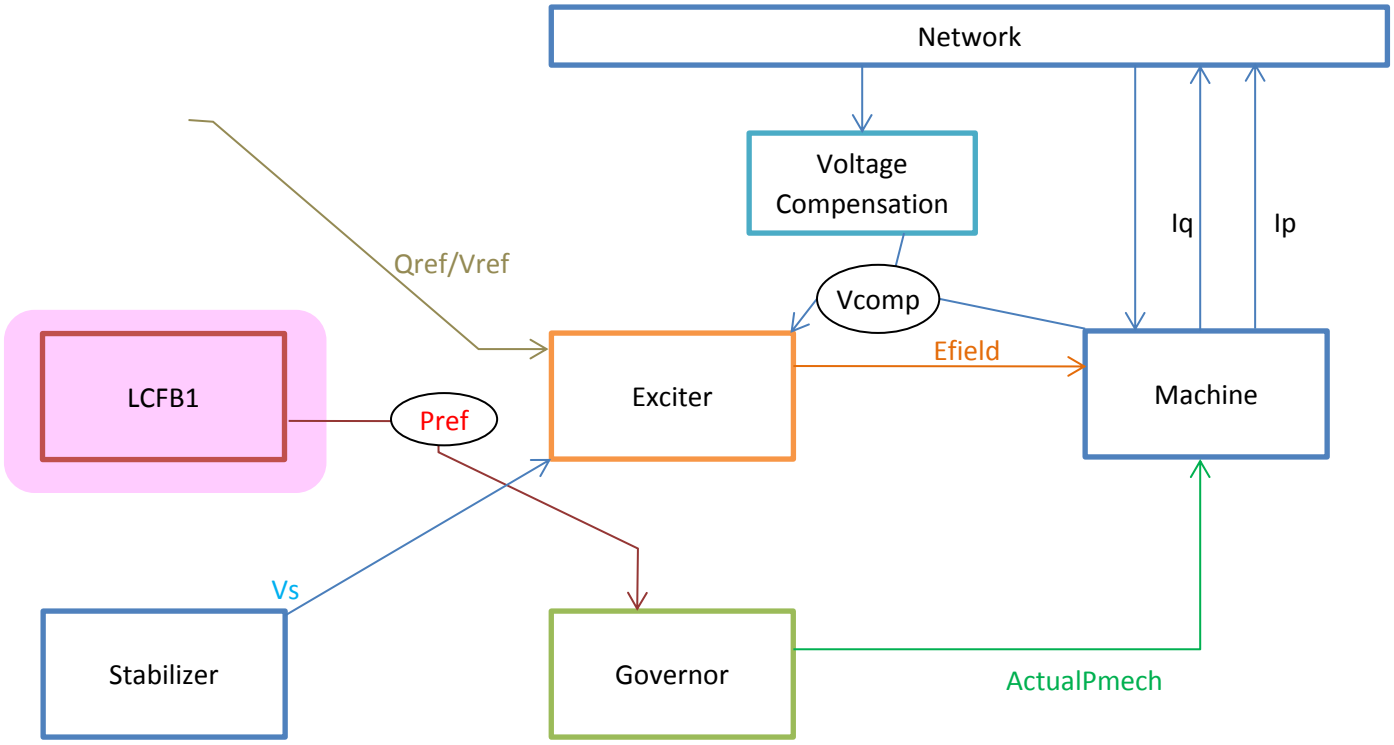
"Traditional" Synchronous Machine Modules



Modular Approach to Generator Modeling

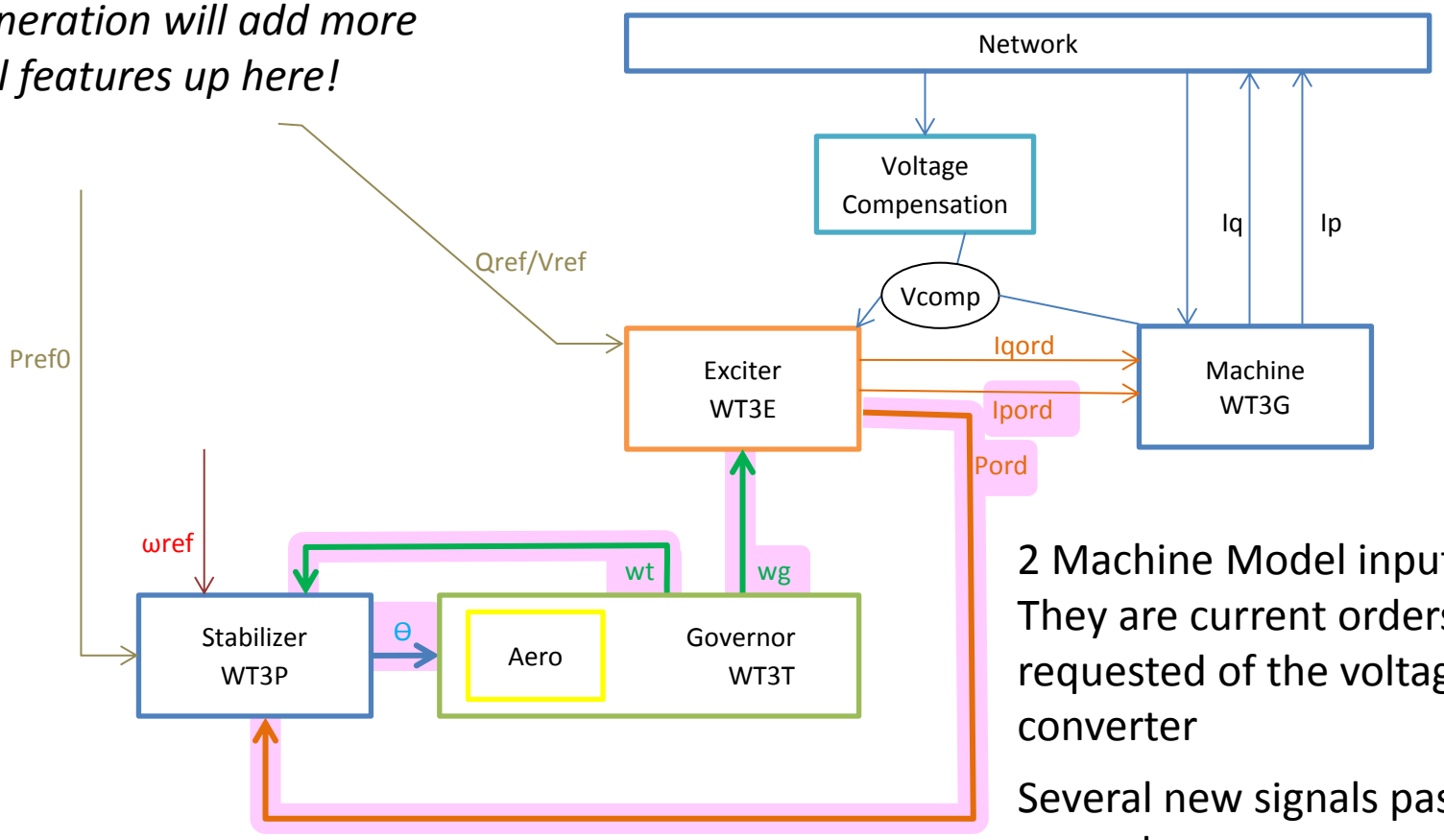
- First generation wind turbine models stuck with this structure
  - Added additional signals to pass between modules
  - Don't get hung up on nomenclature "Exciter" just means the electrical control
- Unrelated to wind turbine modeling, another module was added for better modeling of large steam plants
  - LCFB1 – extra controller feeding the governor allowing control of *Pref*

LCFB1 model: Controller for Pref



First Generation Type 3 Wind Turbine (WT3G, WT3E, WT3T, WT3P)

2nd Generation will add more control features up here!



2 Machine Model inputs now. They are current orders requested of the voltage source converter

Several new signals passing around

Limitations of First Generation Wind Models

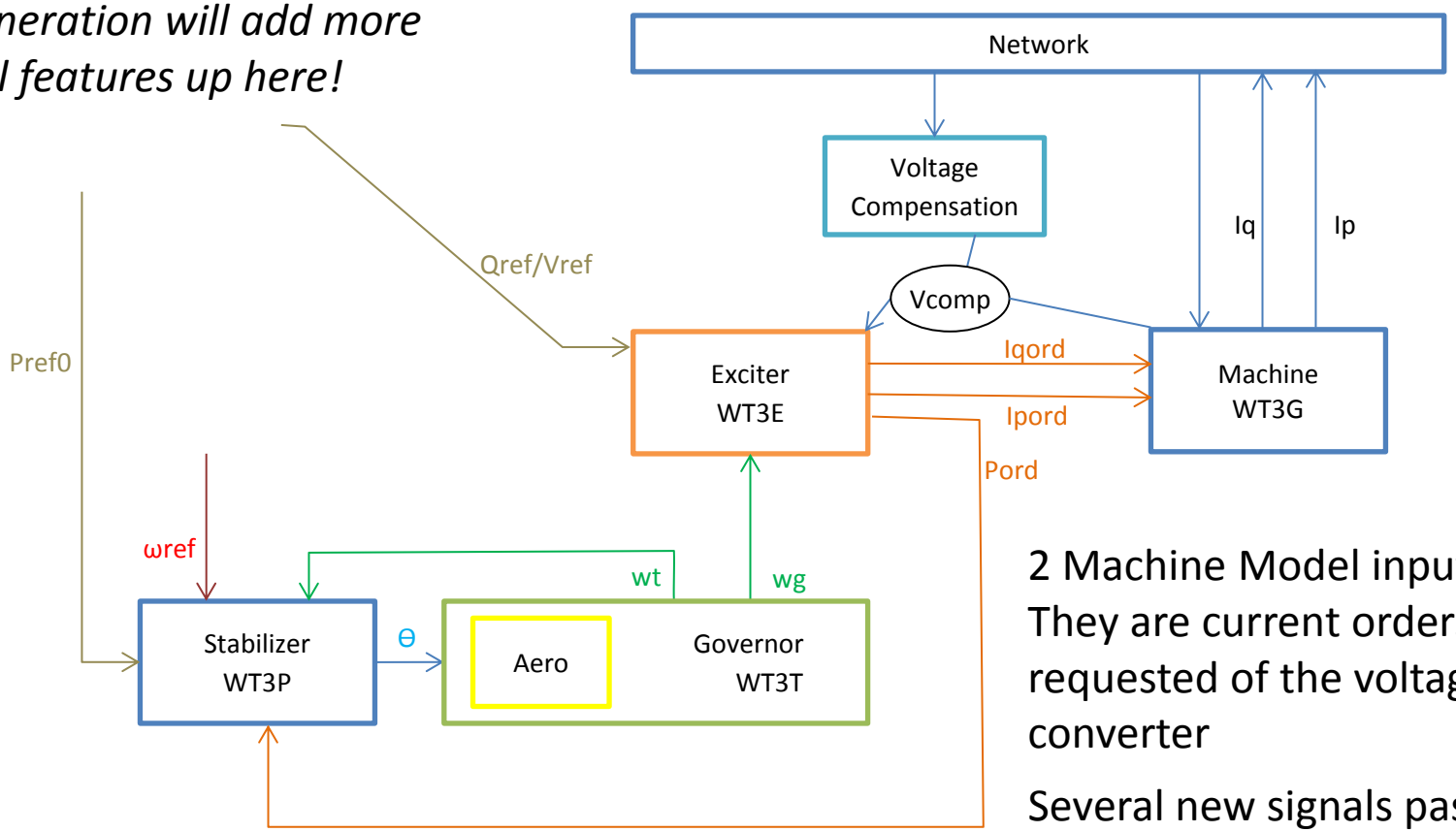
- First Generation model had few mechanisms to provide control features of
  - Real Power or Torque Control
  - Reactive Power
  - Voltage Control
  - For First Generation models, the wind turbine basically tried to bring values back to the initial condition
    - Pref bring power back to initial Power
    - Qref or Vref or PowerFactorRec

Comparing First and Second Generation Models

- Many parts actually change very little
  - "Machine": Voltage Source Converter model of the generator is nearly identical
    - REGC_A is pretty much the same as WT3G/WT4G
  - "Governor": Mechanical Model of wind turbine is identical
    - Combination of WTGT_A and WTGAR_A is *identical* to WT3T
  - "Stabilizer": Pitch Control model has only a small addition
    - WT3P is pretty much same as WTGPT_A
- What's Different – Control System Models
  - The WT3E and WT4E models essentially embedded voltage control and power control inside the model
  - This is now split into separate models
    - REEC_A: models only control with setpoints are as inputs to this model. Control features a little more flexible than the WT3E and WT4E models
    - WTGTRQ_A: control system resulting in the output of PRef
    - REPC_A : control system resulting in output of both a P and V/Q signal

First Generation Type 3 Wind Turbine (WT3G, WT3E, WT3T, WT3P)

2nd Generation will add more control features up here!



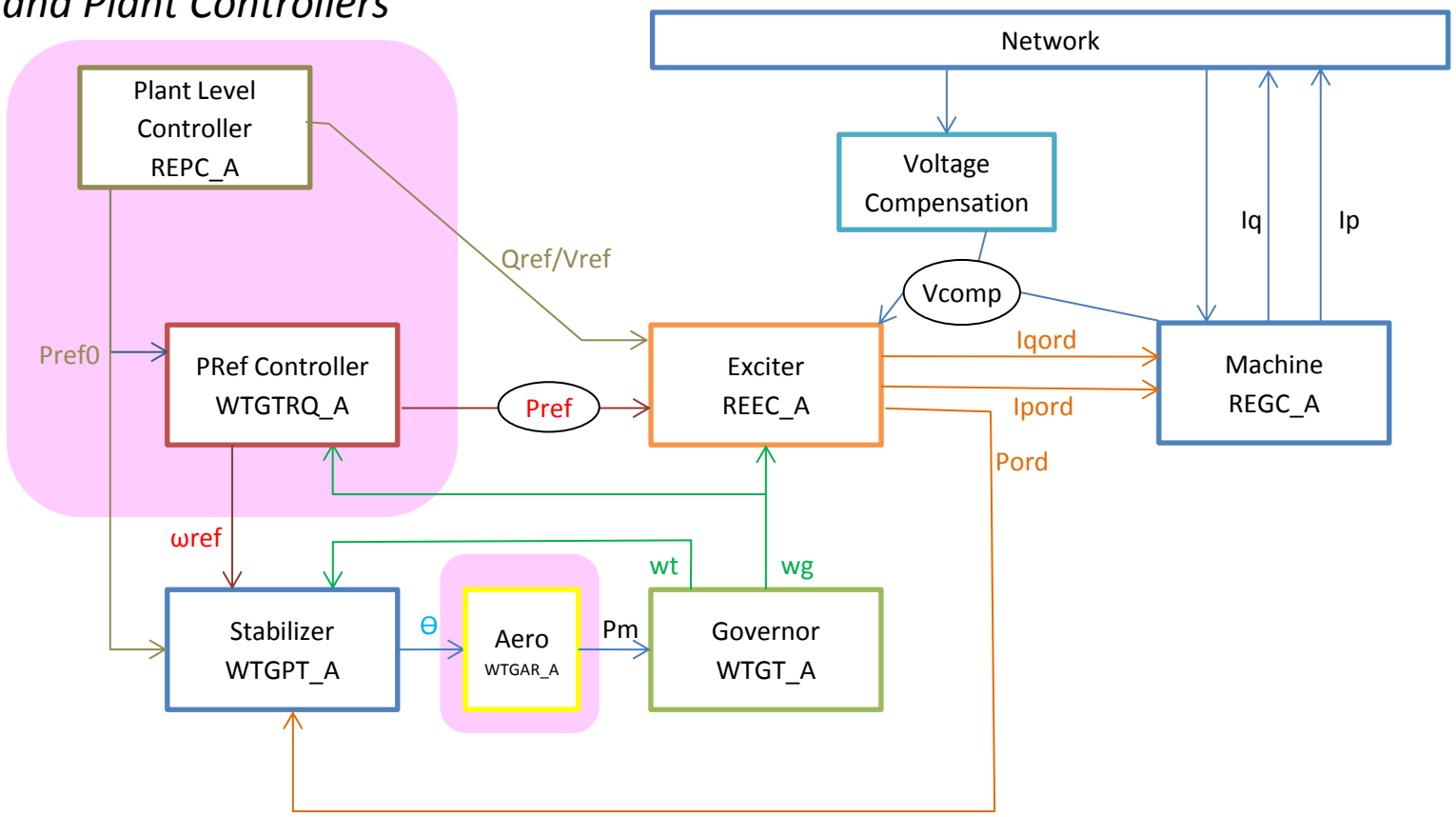
2 Machine Model inputs now. They are current orders requested of the voltage source converter

Several new signals passing around

2nd Generation Type 3 Wind Turbine

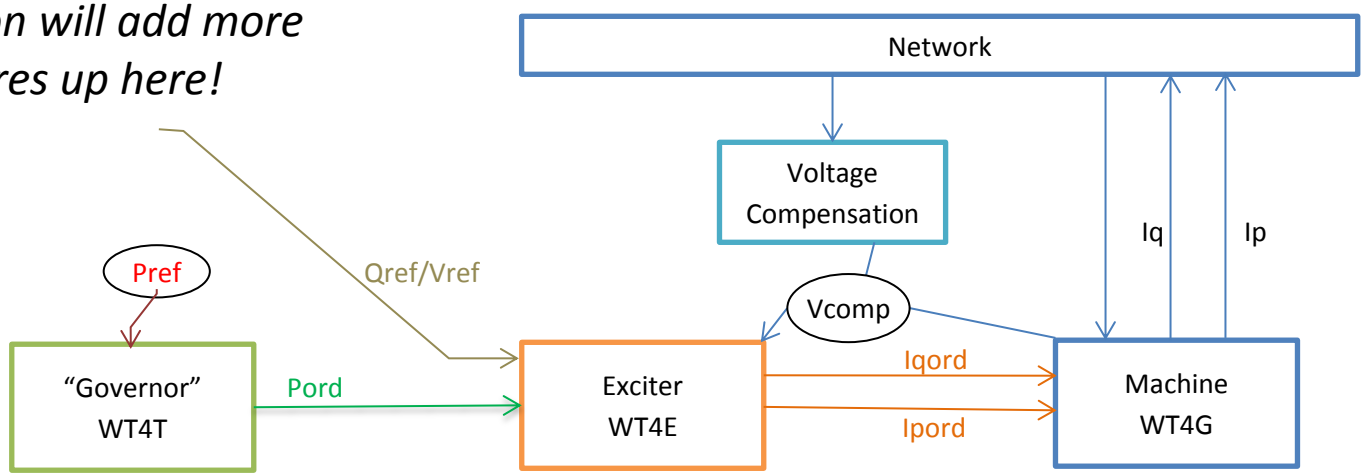
(REGC_A, REEC_A, WTGT_A, WTGAR_A, WTGPT_A, WTGTRQ_A, REPC_A)

2nd Generation adds the Aero, PRef and Plant Controllers



First Generation Type 4 Wind Turbine (WT4G, WT4E, WT4T)

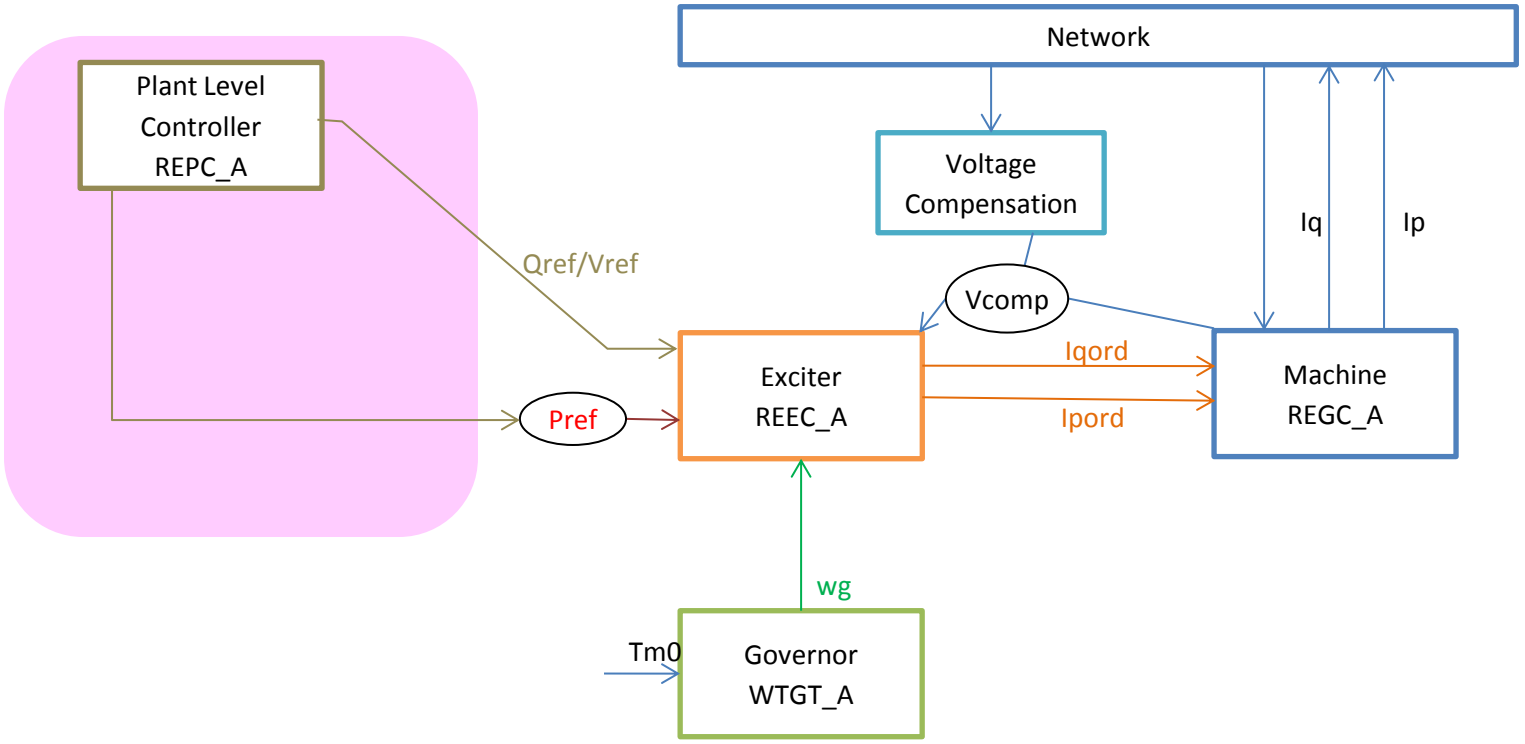
2nd Generation will add more control features up here!



Legacy "Governor" WT4T
This really acts like the new PRef controller

We will leave it in the toolbox as a "Governor" anyway

2nd Generation Type 4 Wind Turbine (REGC_A, REEC_A, WTGT_A, REPC_A)



Note: If REEC_A parameter Pflag = 0, then WTGT_A really doesn't do anything so it can be omitted completely

Software Implementation

- PowerWorld has kept the existing general classes of generator models
  - Machine (Generator/Converter Model)
  - Exciter (P and Q controller)
  - Governor (Drive Train)
  - Stabilizer (Pitch Control)
  - Relay Model
  - Under Excitation Limiter
  - Over Excitation Limiter
  - Compensator Model
- Added 3 new types of generator modules
  - Aerodynamic Model
  - Pref Controller
  - Plant Controller

Scope of new Modules

- Aerodynamic Model
  - Can only be used with Type 3 wind turbine
- Pref Controller
  - Can be used with any type of generator
  - Existing model LCFB1 is now a Pref Controller
  - Pref Signal Output
    - Feeds into Governor if governor accepts Pref
    - Else feeds into Exciter if exciter accepts Pref
- Plant Controller
  - Can be used with any type of generator
  - Existing model PLAYINREF is now a Plant Controller
  - Vref/Qref Signal Output
    - Vref/Qref signal will feed into Exciter if the exciter accepts it
  - Pref Signal Output
    - Pref feeds into Pref Controller if it exists
    - Else feeds into Governor if governor accepts Pref
    - Else feeds into Exciter if exciter accepts Pref

Error Checking

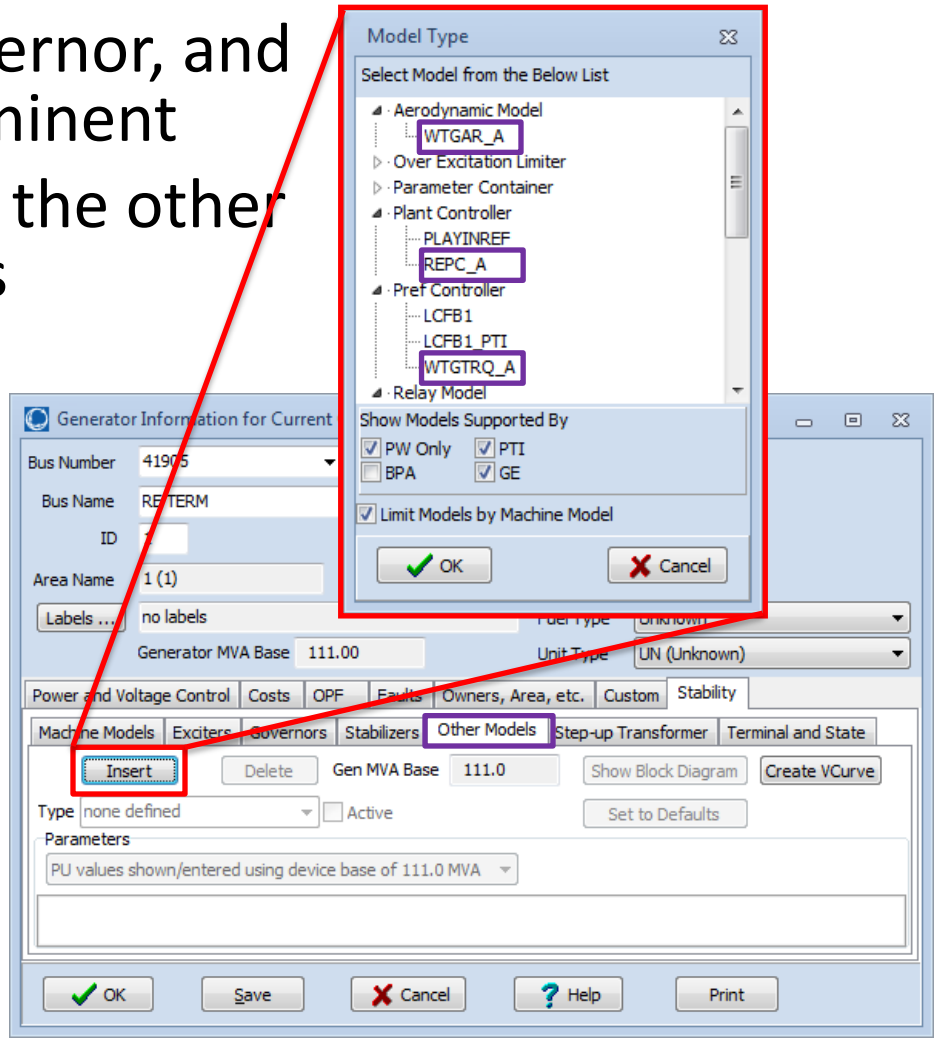
- Error checking is performed when validation is done
  - Ensure there is only 1 Pref controller defined
  - Ensure there is only 1 Plant controller defined
  - Ensure there is only 1 Aerodynamic model
    - Also note, if an aerodynamic model is required between the stabilizer and the governor (WTGPT_A and WTGT_A), but one is not defined, Simulator assumes a WTGAR_A exists with Ka = 0.007 and Theta = 0
- General error checking is done to make sure the model mix makes sense
  - GENTPF can't have a REEC_A "exciter"

Initialization Notes

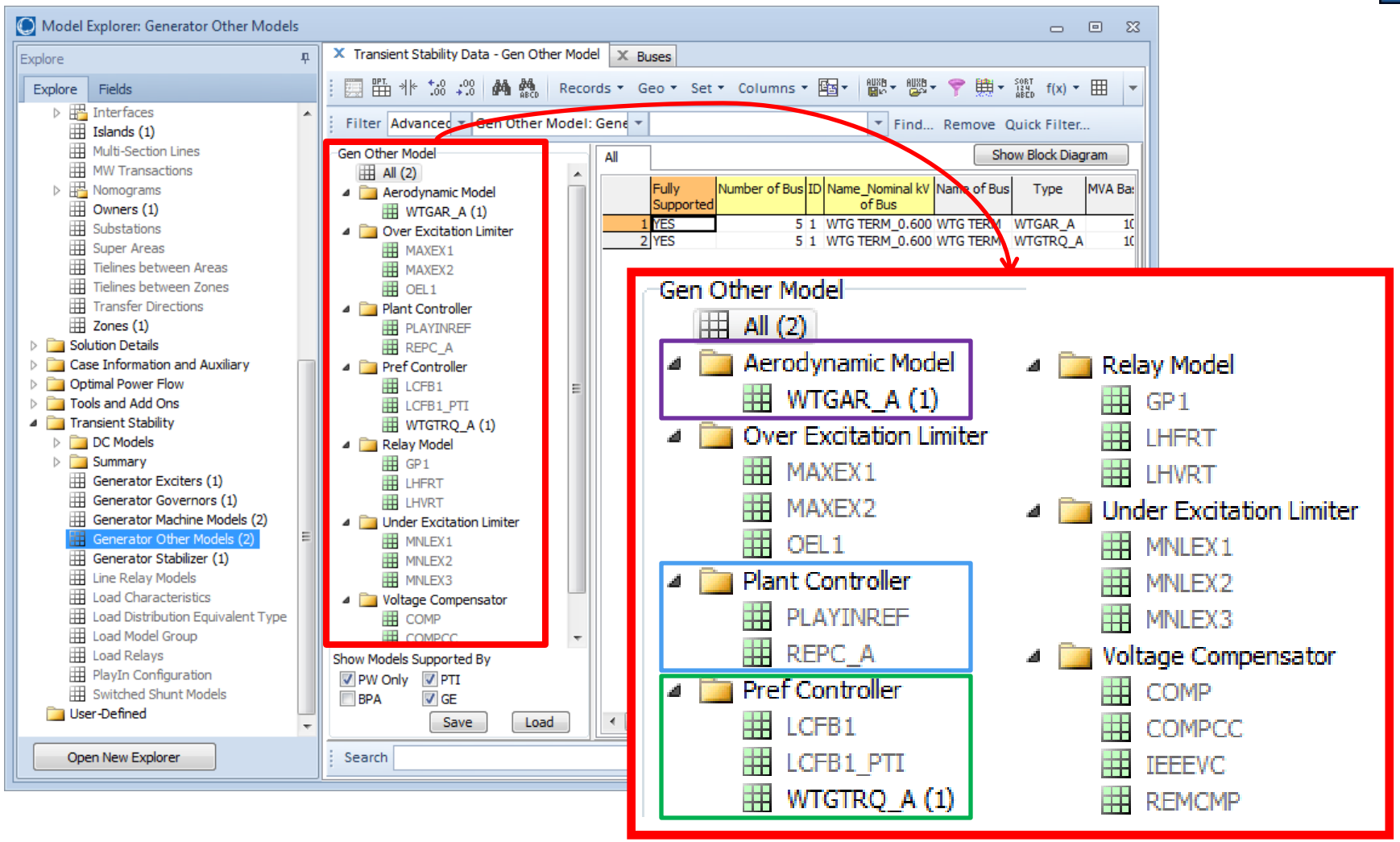
- Because of the way these various blocks connect together, the initialization order of the blocks important
  - Example: the "initial speed" of the wind turbine is calculated in different places
    - For 1st Gen Type 3 → WT3E *(Exciter)*
    - For 2nd Gen Type 3 → WTGTRQ_A *(PRef controller)*
    - For 2nd Gen Type 4 → WTGT_A *(Governor)*
  - This is all handled internally by Simulator so the user does not need to be concerned with the order

Where does it appear in GUI

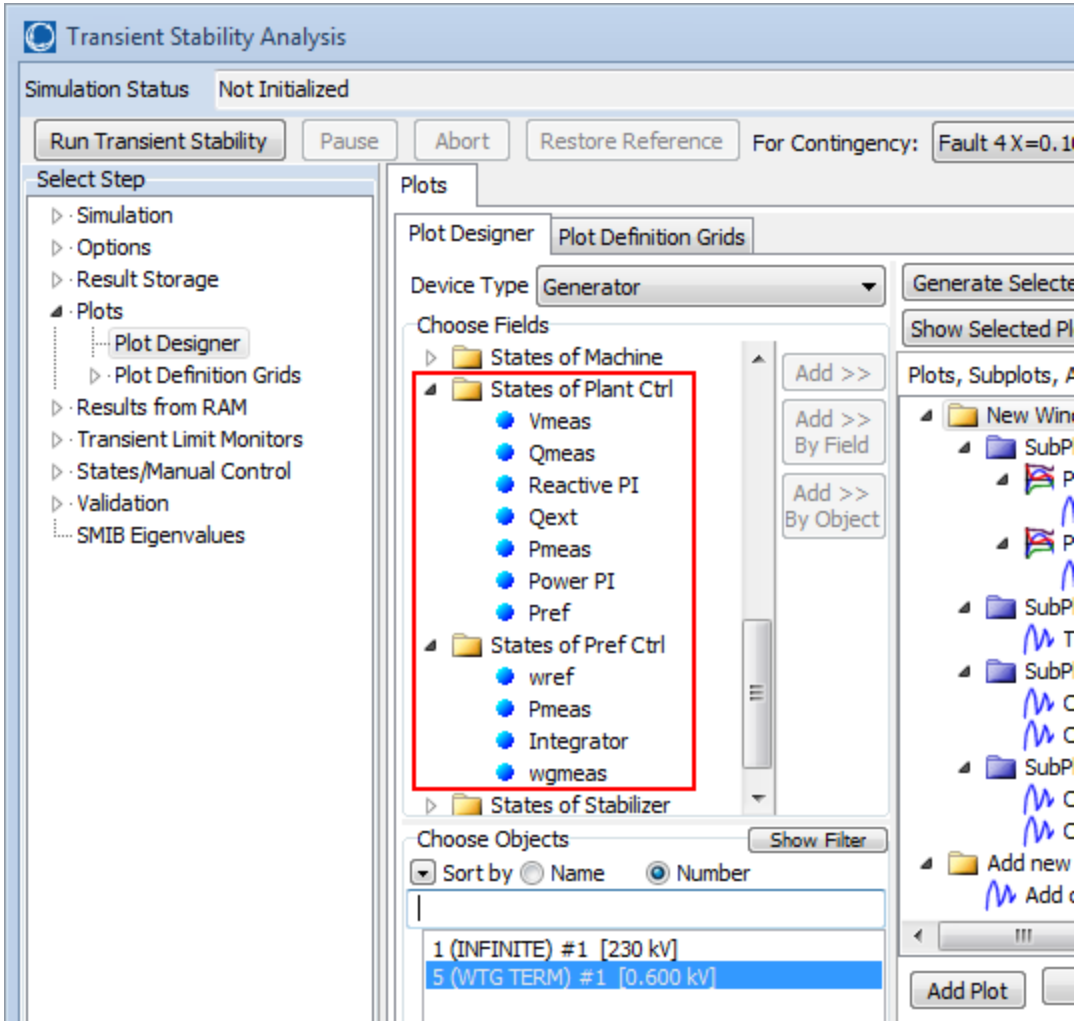
- Machine, Exciter, Governor, and Stabilizer remain prominent
- *Other Models* contain the other categories of modules
- You see it in the Model Explorer
- When inserting a new *Other Model* from the generator dialog
- Plot Designer in Transient Stability Dialog

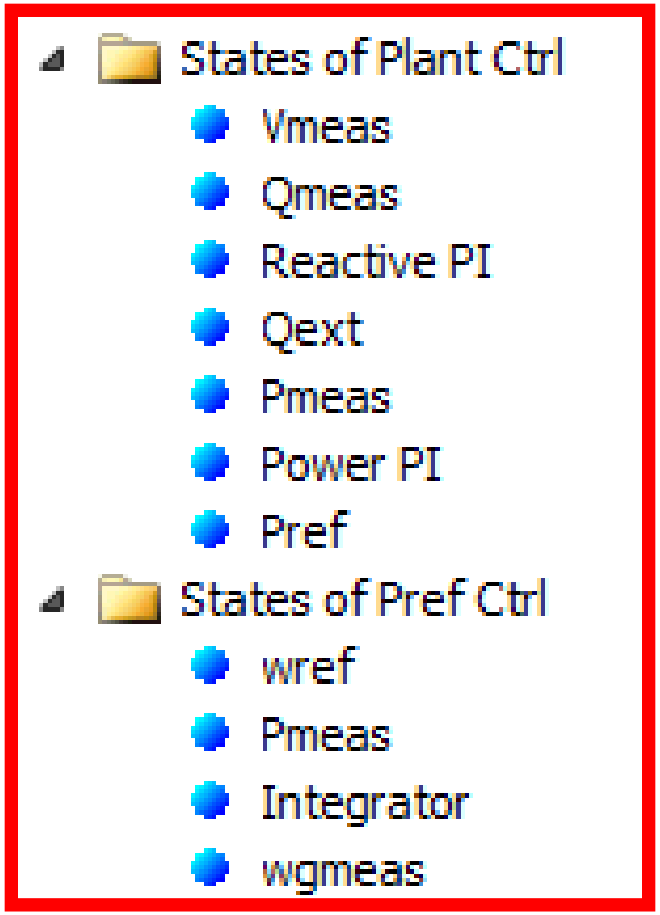


Model Explorer



Plot Designer



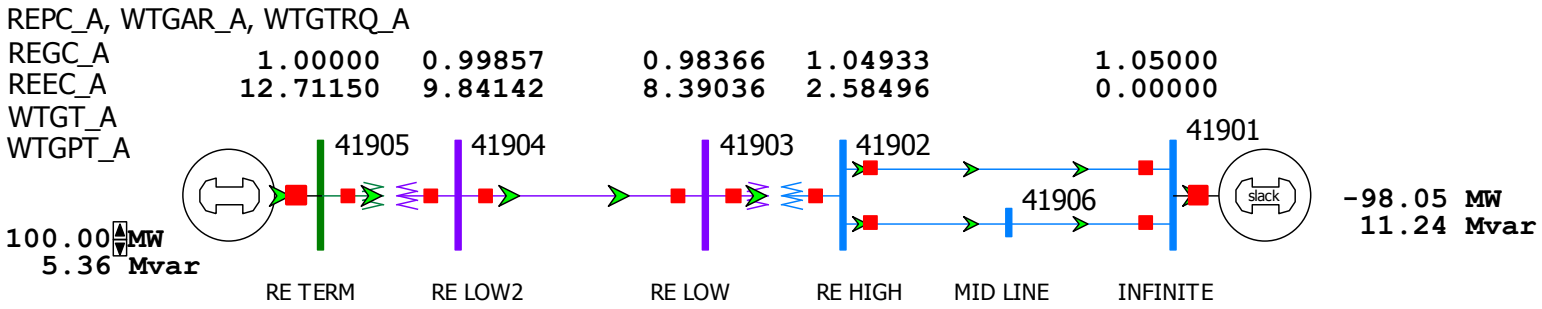


Implementation Status: PowerWorld Simulator 18

- All of the following models were released in Version 18 of PowerWorld Simulator
- New Renewable Models
  - Type 3 Wind Turbine
    - REGC_A, REEC_A, WTGT_A, WTGPT_A, WTGAR_A, REPC_A, WTGTRQ_A
  - Type 4 Wind Turbine
    - REGC_A, REEC_A, WTGT_A, REPC_A
  - Solar PV Models
    - REGC_A, REEC_B, REPC_A
      - REEC_B is just a variation of REEC_A with less parameters and features
  - New Pitch Control for Type 1 and 2 Wind Turbines
    - WT1P_B

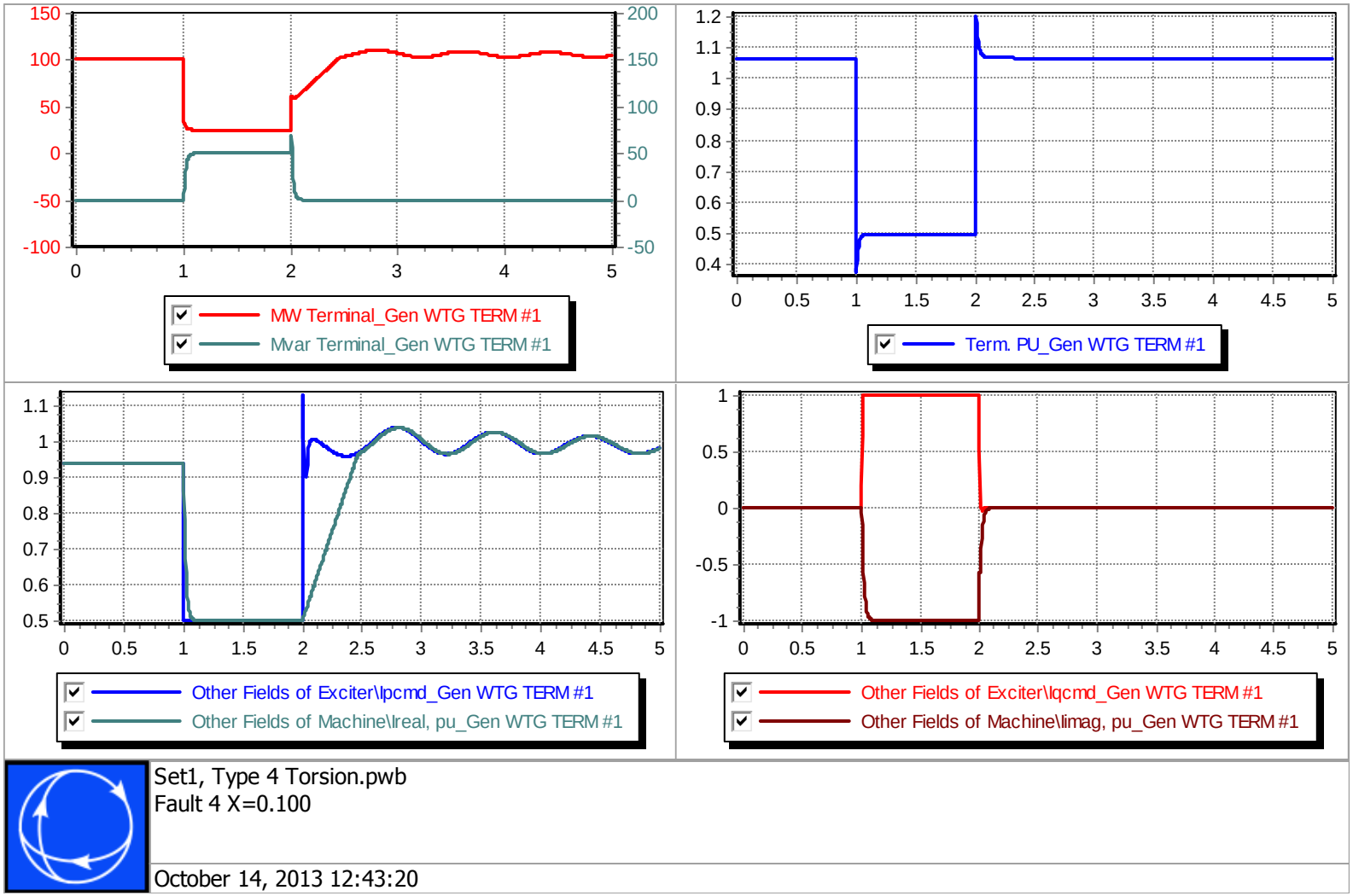
Demonstration

- Pouyan Pourbeik created a small system to test these models in October 2013



- Model the wind turbine on the left and then an infinite bus on the right
- Testing is showing agreement among all software treatment of the new models

Sample Results



Sample Simulations

- Ryan Elliot from Sandia National Labs made some more sample simulation results to compare to for this meeting
  - RenewableDemo.epc
  - pv_plant_generic.dyd
  - wtg_generic_type3.dyd
  - wtg_generic_type4.dyd
- You can open these directly in PowerWorld Simulator
  - File>Open Case>
  - File>Load Transient Stability Data>

Demonstration in Simulator

- A Knowledge Base article is available on the PowerWorld Corporation website which goes through this example.
  - http://www.powerworld.com/knowledge-base/renewable-transient-stability-modeling-for-wind-and-solar-plants