

# Wind Turbine Models in PowerWorld Simulator



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# Power Flow Models of Renewable Generation Plants

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- 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



Generator Information for Current Case

Bus Number: 41905  
 Bus Name: RE TERM  
 ID: 1  
 Area Name: 1 (1)  
 Labels: no labels  
 Generator MVA Base: 111.00

Status:  Open,  Closed  
 Energized:  NO (Offline),  YES (Online)  
 Fuel Type: Unknown  
 Unit Type: UN (Unknown)

Power and Voltage Control: Costs, OPF, Faults, Owners, Area, etc., Custom, Stability

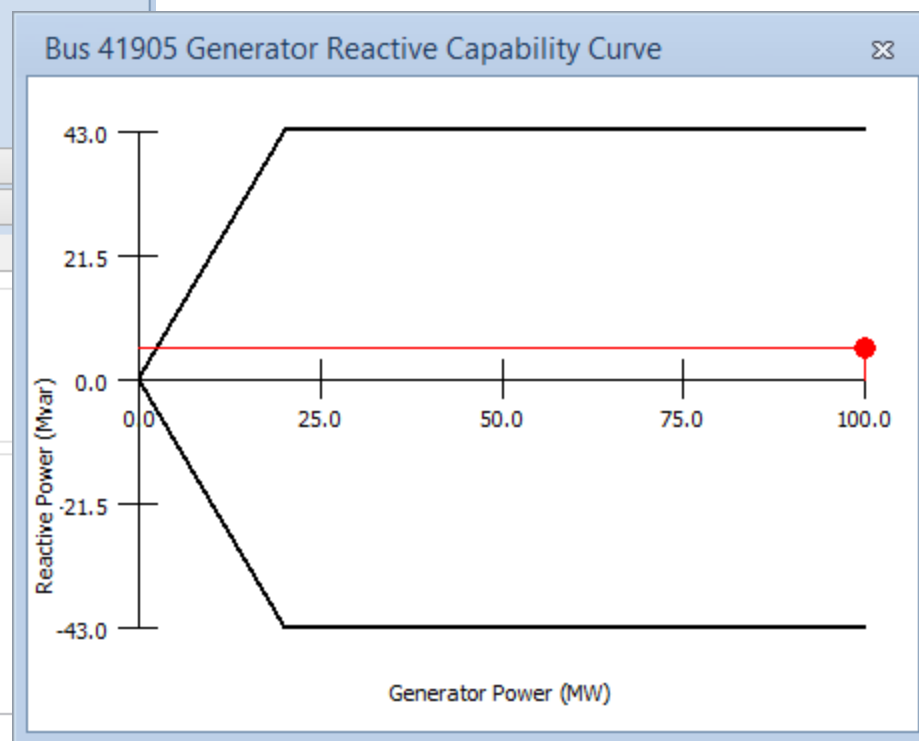
Power Control  
 MW Output: 100.000, Available for AGC: , Participation Factor: 100.00  
 Min. MW Output: 0.000, Enforce MW Limits: , Loss Sensitivity: 0.0000  
 Max. MW Output: 100.000

Voltage Control  
 Mvar Output: 5.357, Available for AVR: , Regulated Bus Number: 41905  
 Min Mvar: -43.000, Use Capability Curve: , Desired Reg. Bus Voltage: 1.0000  
 Max Mvar: 43.000, Actual Reg. Bus Voltage: 1.0000

Wind Control Mode  
 Mode: None, Power Factor: 0.9500, Remote Reg %: 100.0

MW	0.000	20.000	100.000
Min Mvar	-0.100	-43.000	-43.000
Max Mvar	0.100	43.000	43.000

Buttons: OK, Save, Cancel, Help, Print



# Mvar Capability Curves: Wind Control Mode = Boundary



**Generator Information for Current Case**

Bus Number: 41905  
Bus Name: RE TERM  
ID: 1  
Area Name: 1 (1)  
Generator MVA Base: 111.00

Status:  Open  Closed  
Energized:  NO (Offline)  YES (Online)  
Fuel Type: Unkr  
Unit Type: UN

Power and Voltage Control: Costs, OPF, Faults, Owners, Area, etc., Custom

**Power Control**  
MW Output: 100.000  Available for AGC Participation Factor: 100.000  
Min. MW Output: 0.000  Enforce MW Limits Loss Sensitivity: 0.000  
Max. MW Output: 100.000

**Voltage Control**  
Mvar Output: 5.357  Available for AVR Regulated Bus Number: 4  
Min Mvar: -32.868 Desired Reg. Bus Voltage: 1.0000  
Max Mvar: 32.868  Use Capability Curve Actual Reg. Bus Voltage: 1.0000  
Remote Reg %: 100.0

**Wind Control Mode**  
Mode: Boundary Power Factor  
Power Factor: 0.9500

MW	0.000	20.000	100.000
Min Mvar	-0.100	-43.000	-43.000
Max Mvar	0.100	43.000	43.000

**Bus 41905 Generator Reactive Capability Curve**

Reactive Power (Mvar) vs Generator Power (MW)

**Wind Control Mode**  
Mode: Boundary Power Factor  
Power Factor: 0.9500

- None
- Boundary Power Factor
- Constant Power Factor
- Follow Min Mvar Capability Curve

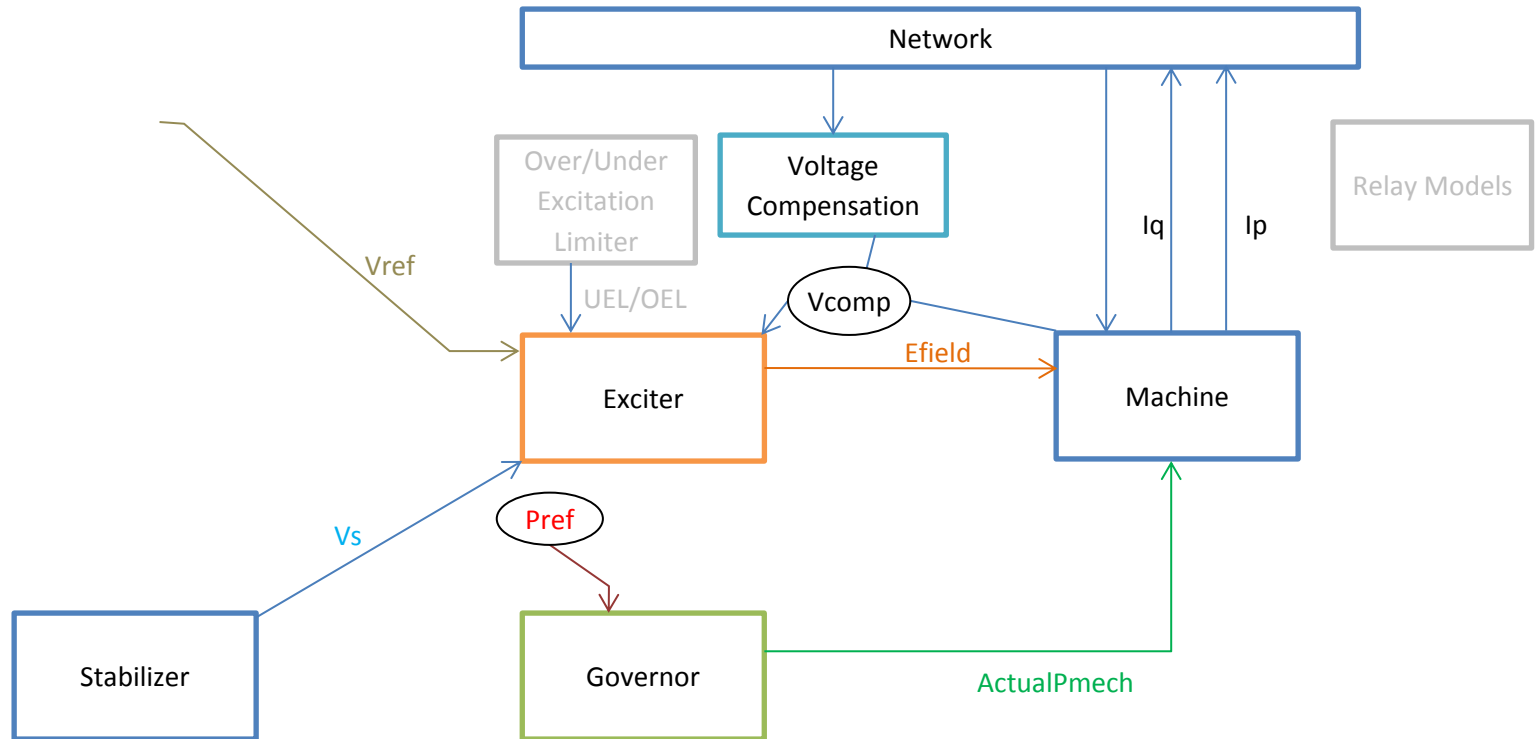
# Modular Approach to Generator Modeling in Transient Stability

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- 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



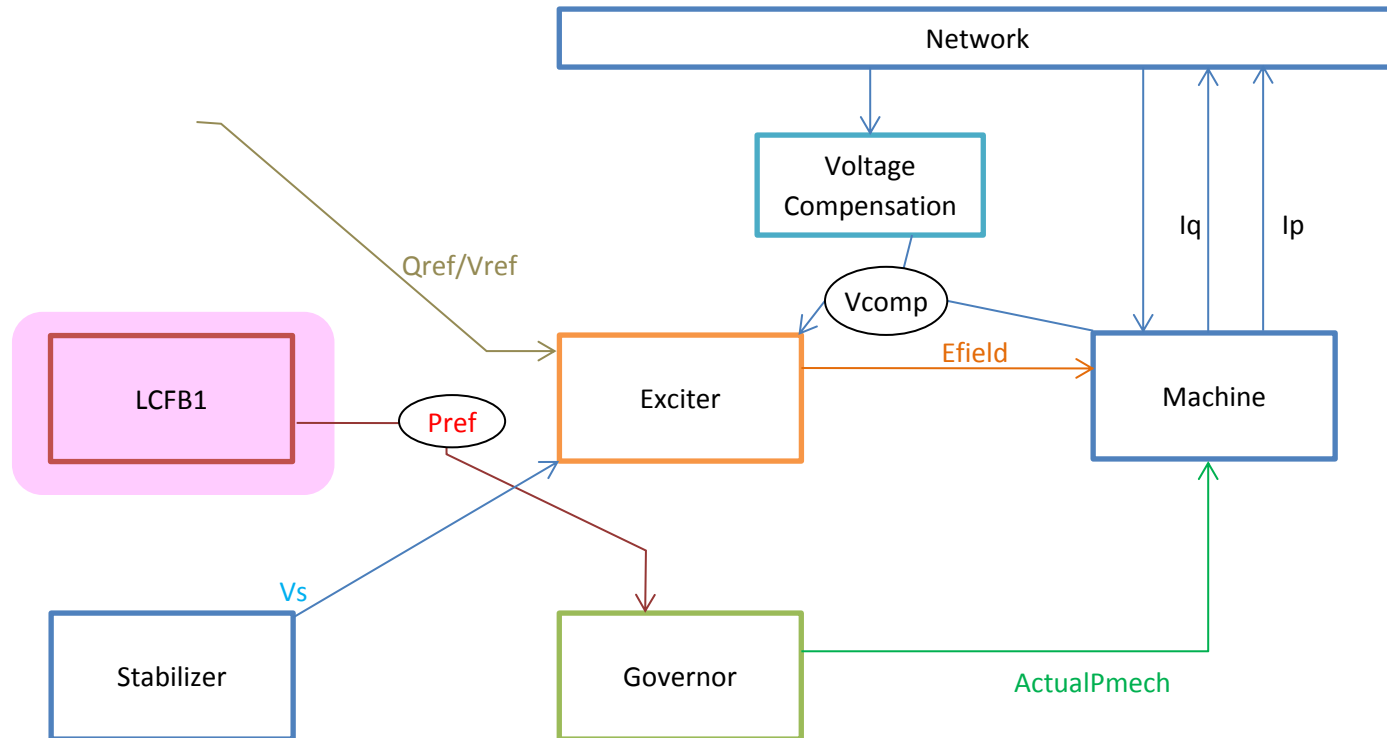
# Modular Approach to Generator Modeling

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- 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

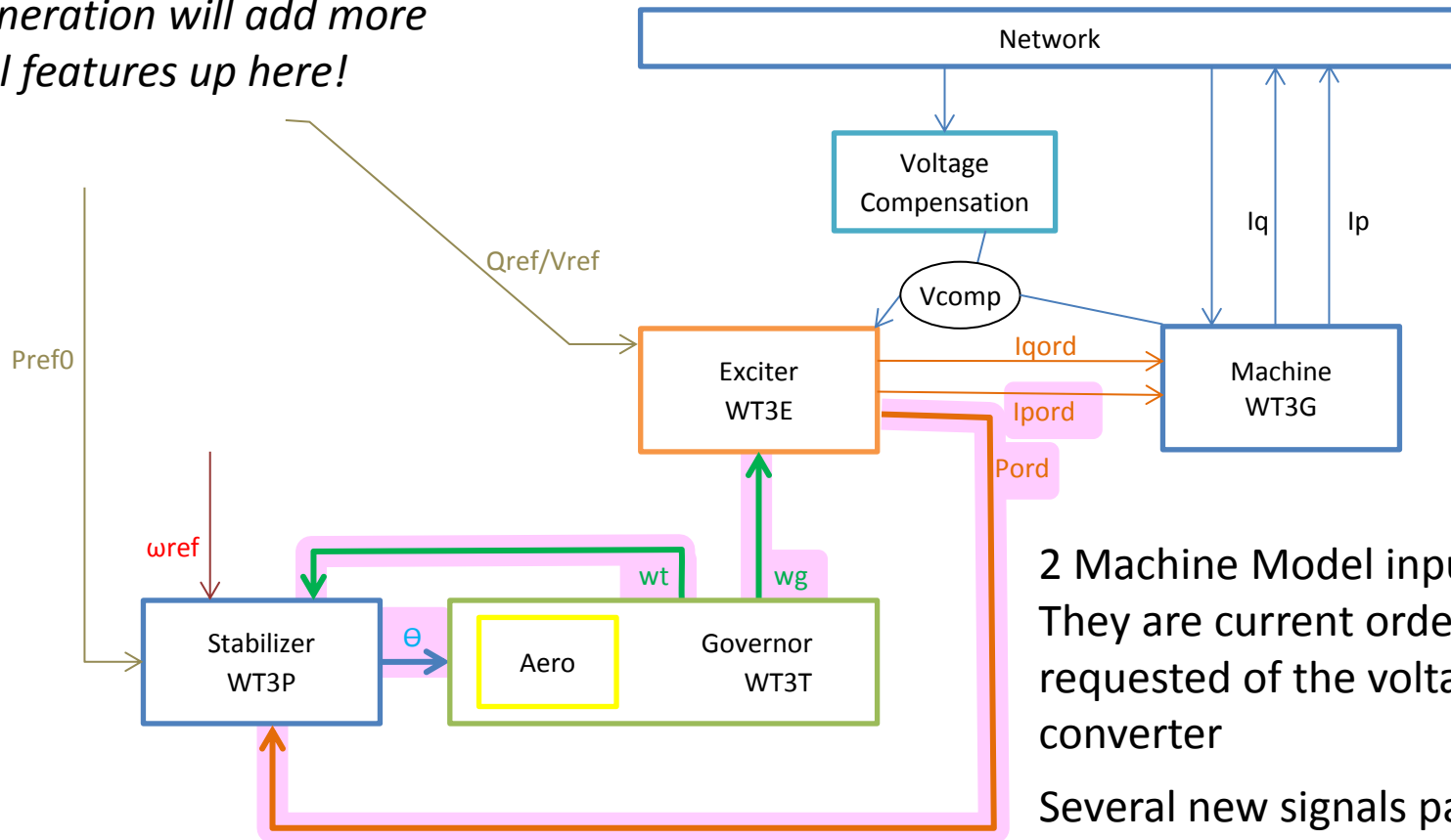




# First Generation Type 3 Wind Turbine (WT3G, WT3E, WT3T, WT3P)



*2<sup>nd</sup> 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

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- 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

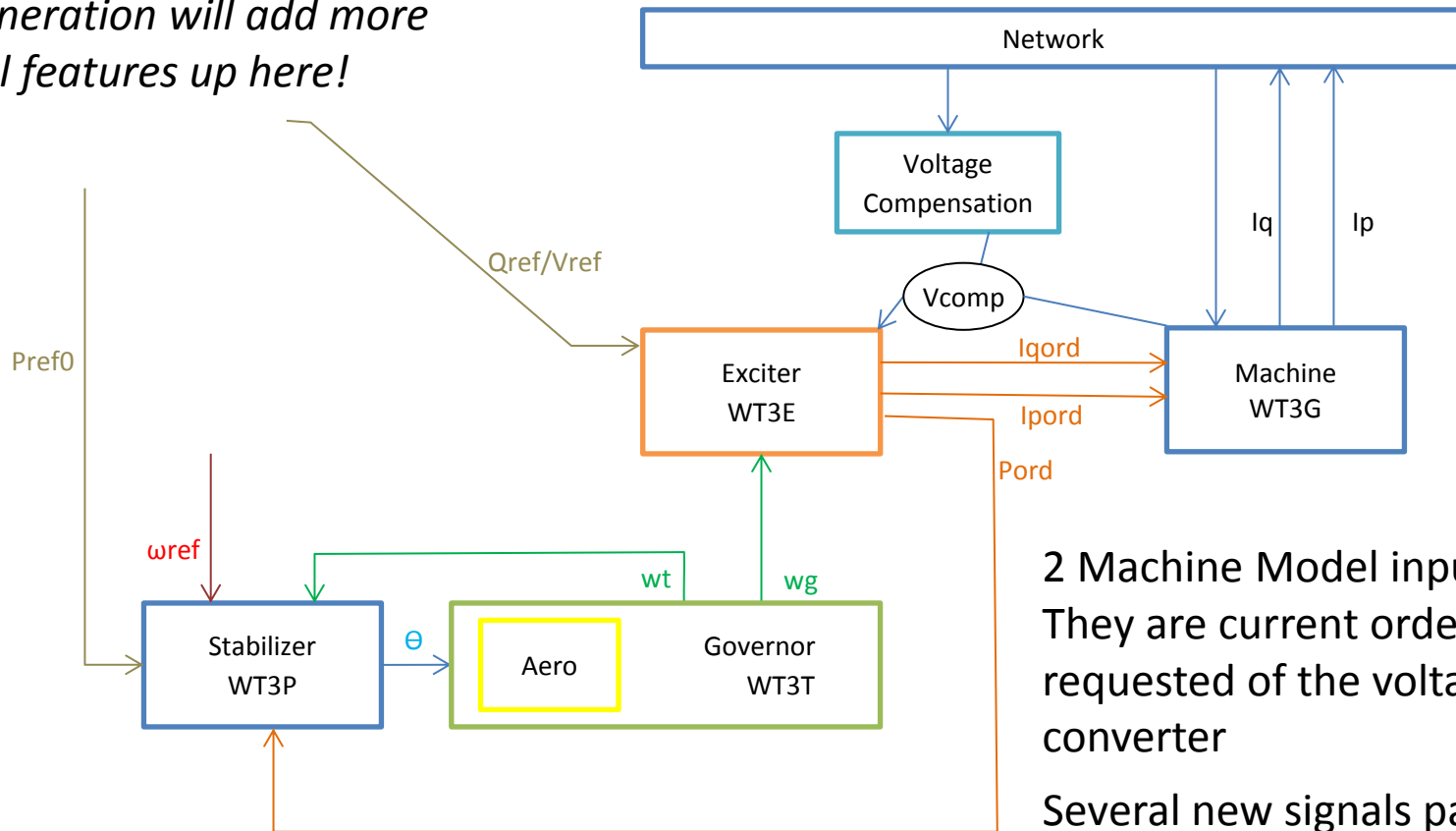


- Many parts actually change very little
  - “Machine”: Voltage Source Converter model of the generator is nearly identical
    - REGC\_A is pretty much the same as WT3G/WT4G
  - “Governor”: Mechanical Model of wind turbine is identical
    - Combination of WTGT\_A and WTGAR\_A is *identical* to WT3T
  - “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)



*2<sup>nd</sup> Generation will add more control features up here!*



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

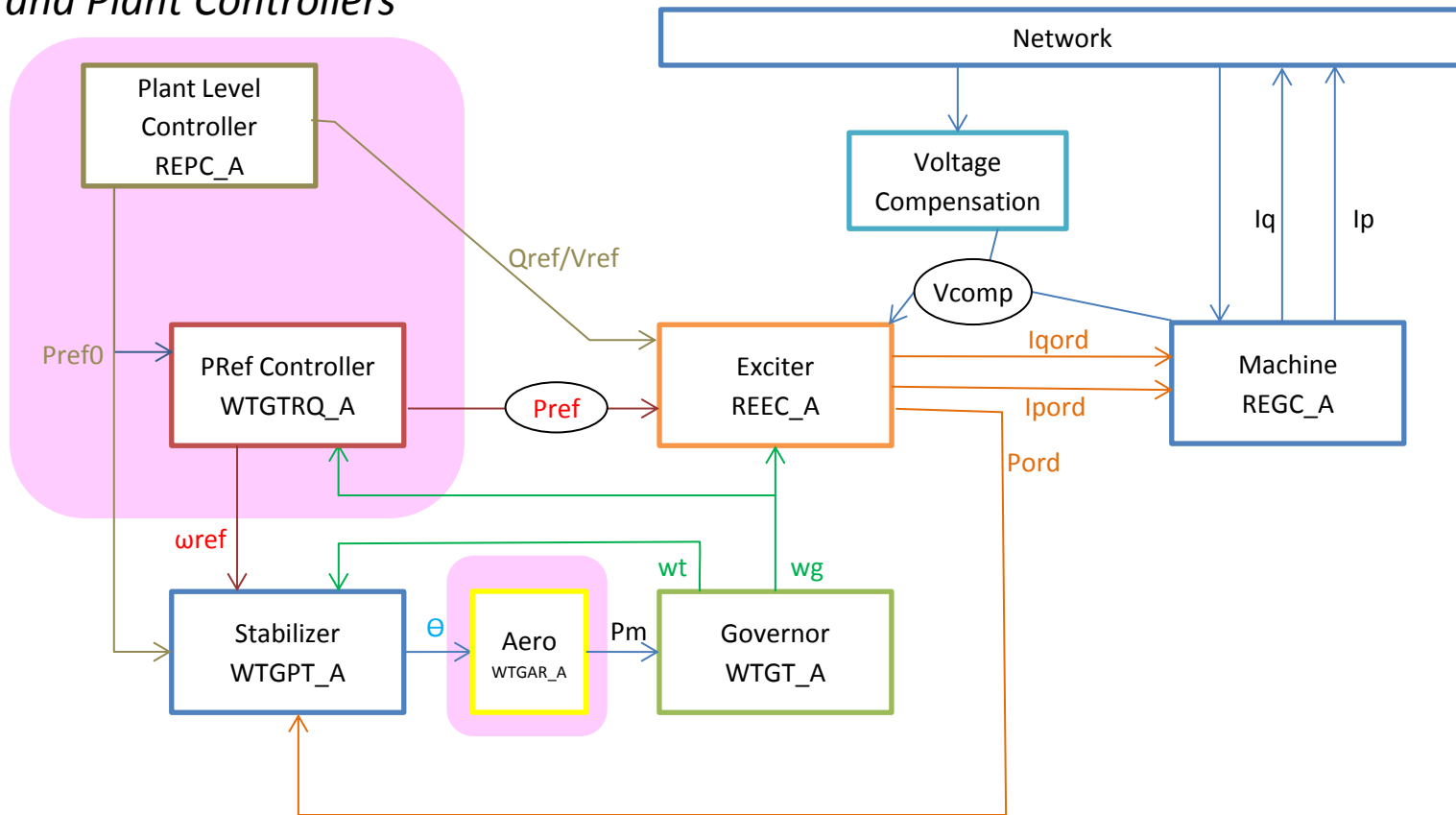
Several new signals passing around

# 2<sup>nd</sup> Generation Type 3 Wind Turbine

(REGC\_A, REEC\_A, WTGT\_A, WTGAR\_A, WTGPT\_A, WTGTRQ\_A, REPC\_A)



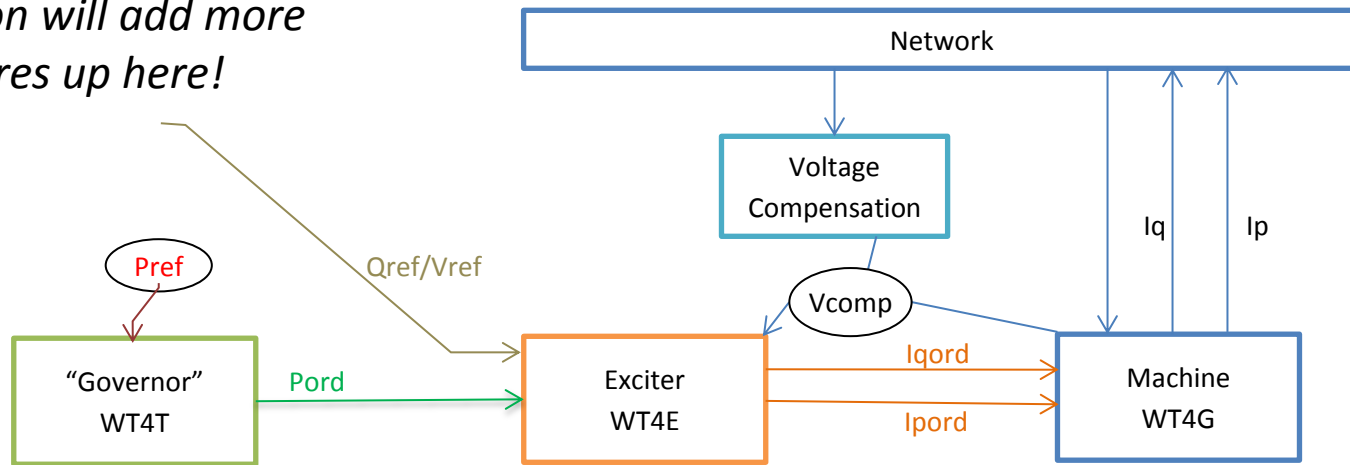
2<sup>nd</sup> Generation adds the Aero,  
PRef and Plant Controllers



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



*2<sup>nd</sup> Generation will add more control features up here!*

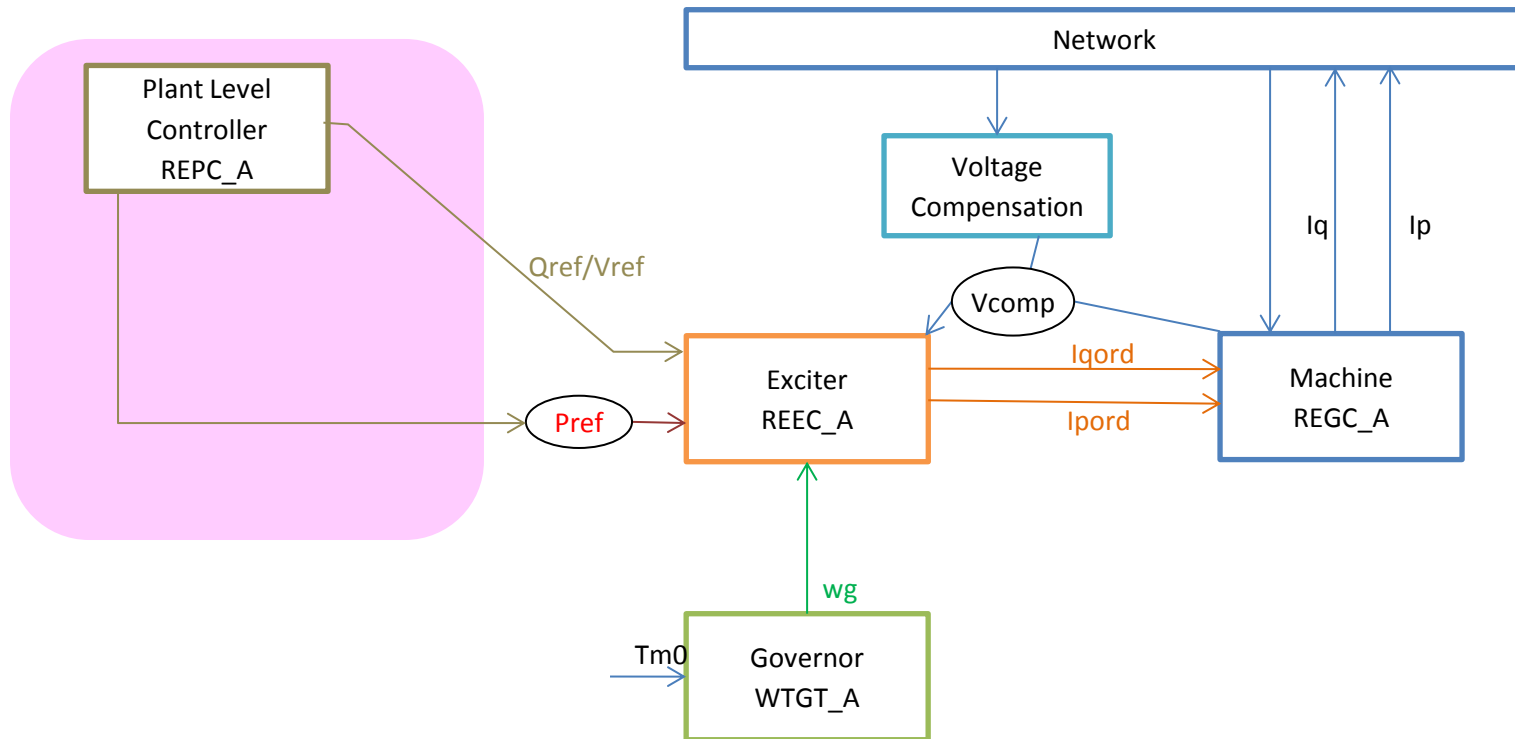


*Legacy "Governor" WT4T*

*This really acts like the new PRef controller*

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

# 2<sup>nd</sup> 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

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- 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  $K_a = 0.007$  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

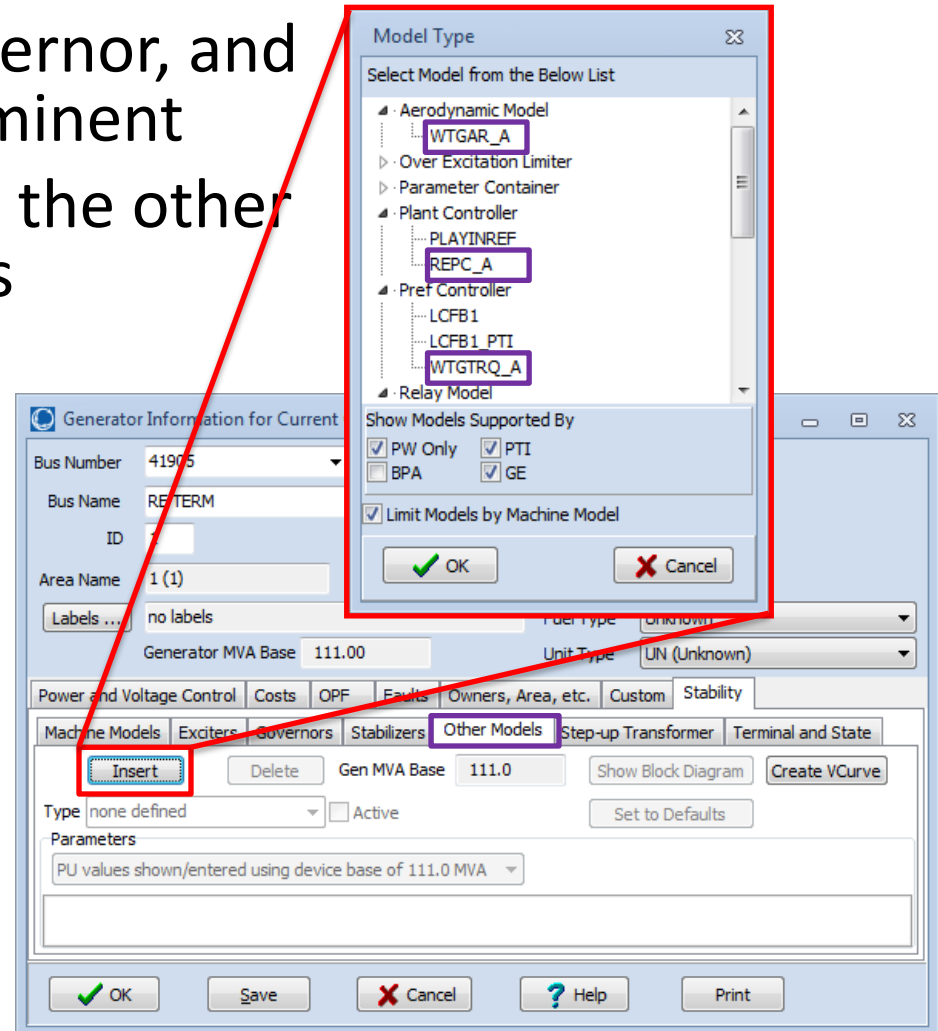


- Because of the way these various blocks connect together, the initialization order of the blocks important
  - Example: the “initial speed” of the wind turbine is calculated in different places
    - For 1<sup>st</sup> Gen Type 3 → WT3E (*Exciter*)
    - For 2<sup>nd</sup> Gen Type 3 → WTGTRQ\_A (*PRef controller*)
    - For 2<sup>nd</sup> 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



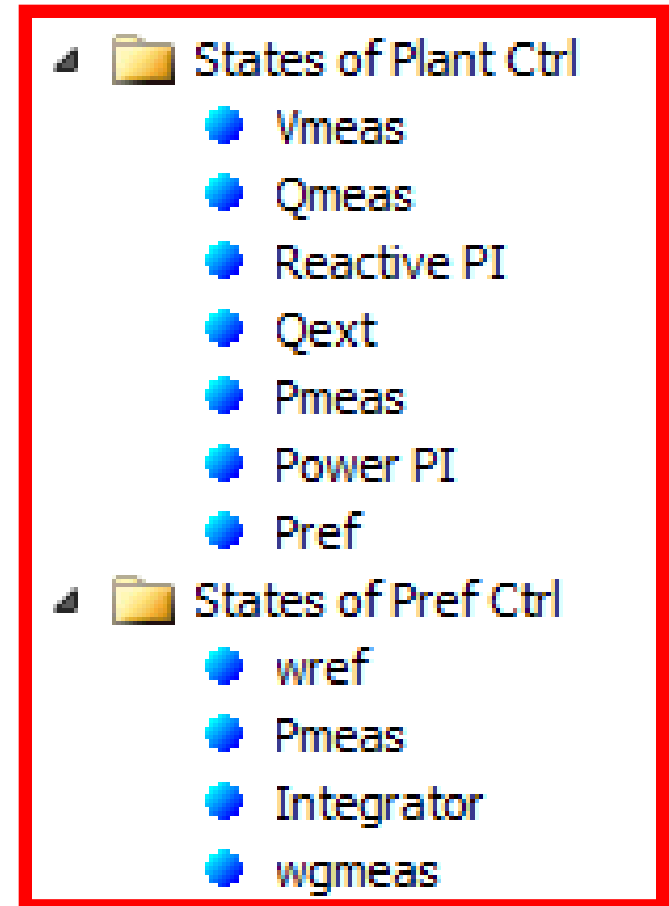
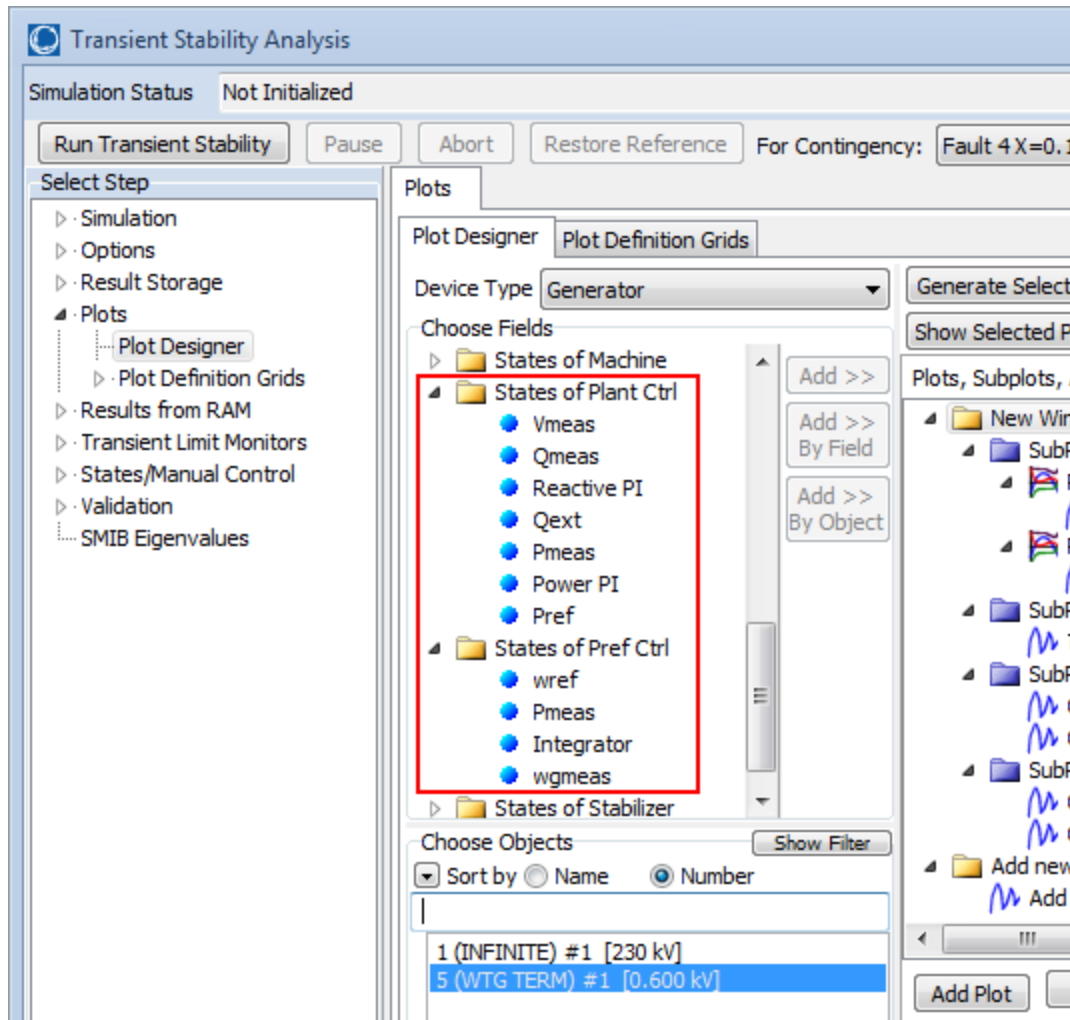
# Model Explorer



The screenshot displays the 'Model Explorer: Generator Other Models' window. The left pane shows a tree view of model categories, with 'Generator Other Models (2)' selected. The main pane shows a detailed view of the 'Gen Other Model' tree, with several sub-models highlighted by colored boxes: 'Aerodynamic Model' (purple), 'Over Excitation Limiter' (blue), 'Plant Controller' (blue), 'Pref Controller' (green), 'Relay Model' (purple), 'Under Excitation Limiter' (purple), and 'Voltage Compensator' (purple). A table in the center-right shows data for 'Fully Supported' models.

Fully Supported	Number of Bus	ID	Name_Nominal kV of Bus	Name of Bus	Type	MVA Ba	
1	YES	5	1	WTG TERM_0.600	WTG TERM	WTGAR_A	10
2	YES	5	1	WTG TERM_0.600	WTG TERM	WTGTRQ_A	10

# Plot Designer



# Implementation Status:

## PowerWorld Simulator 18

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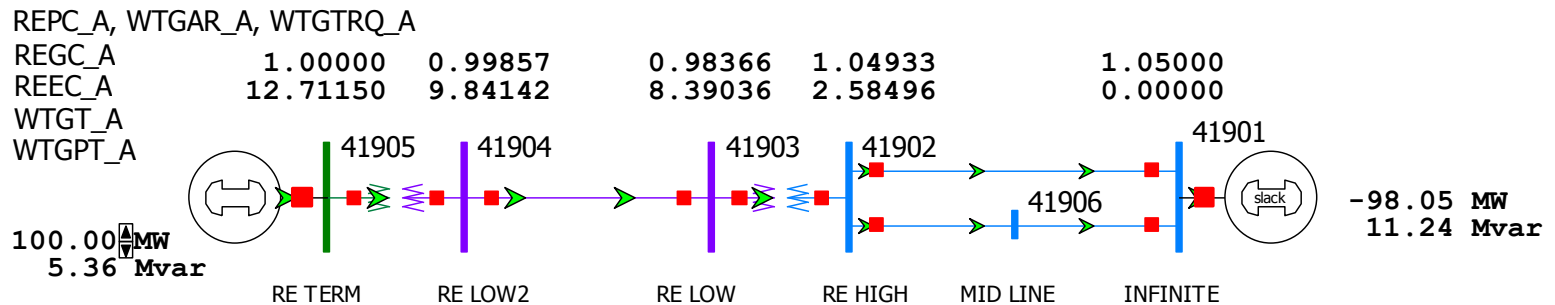


- All of the following models were released in Version 18 of PowerWorld Simulator
- New Renewable Models
  - Type 3 Wind Turbine
    - REGC\_A, REEC\_A, WTGT\_A, WTGPT\_A, WTGAR\_A, REPC\_A, WTGTRQ\_A
  - Type 4 Wind Turbine
    - REGC\_A, REEC\_A, WTGT\_A, REPC\_A
  - Solar PV Models
    - REGC\_A, 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



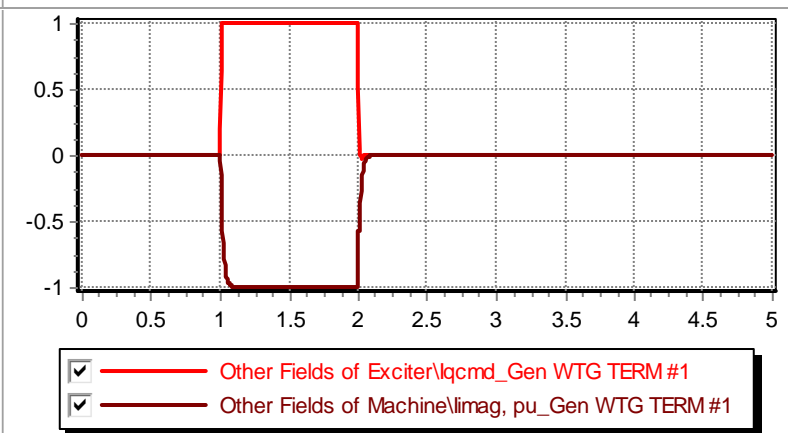
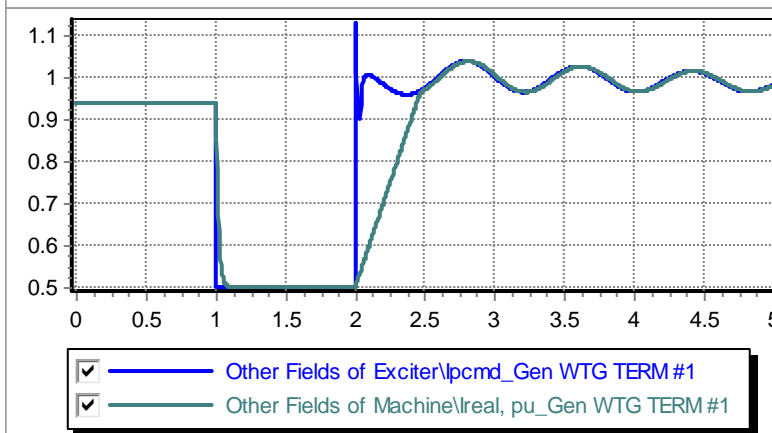
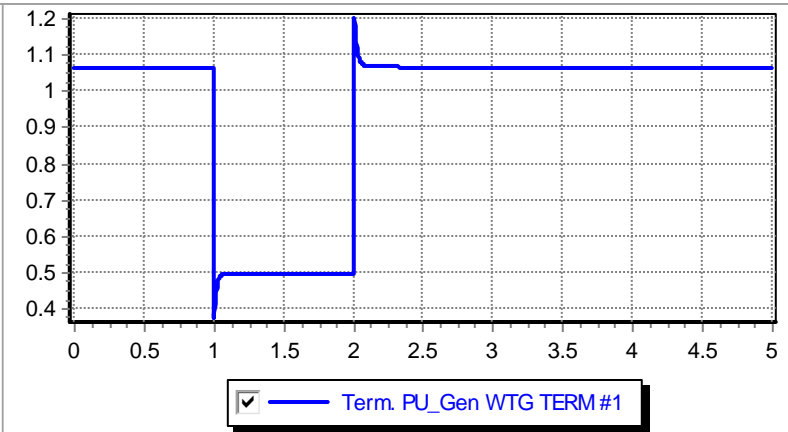
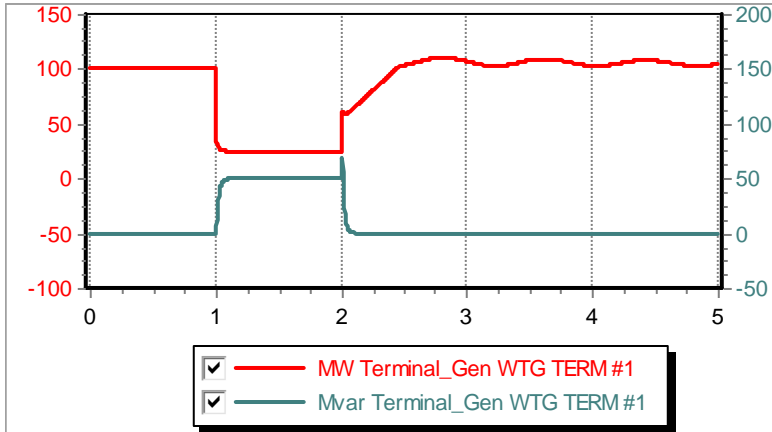
- Pouyan Pourbeik created a small system to test these models in October 2013



- 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



Set1, Type 4 Torsion.pwb  
 Fault 4 X=0.100  
 October 14, 2013 12:43:20

# Sample Simulations

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- 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

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- 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>