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Modeling, Simulation, And Optimization for the 21st Century Electric Power Grid

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Real-Time Dynamic Models for Wind Power Plants

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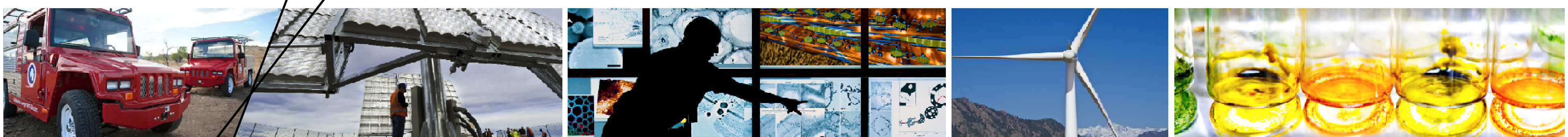
Dynamic Modeling of Wind Power Plants on the Real-Time Digital Simulator Platform



Modeling, Simulation, and Optimization for the 21st Century Electric Power Grid

Mohit Singh, Vahan Gevorgian, Eduard Muljadi

October 23 2012

Objectives

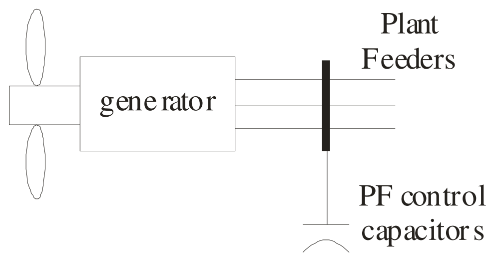
- **To present test cases for wind turbine generator and wind power plant models used during commissioning of wind power plants to ensure grid integration compatibility**
  - To this end, models based on the WECC Wind Generator Modeling Group's standardization efforts are implemented on a real-time digital simulator

Motivation

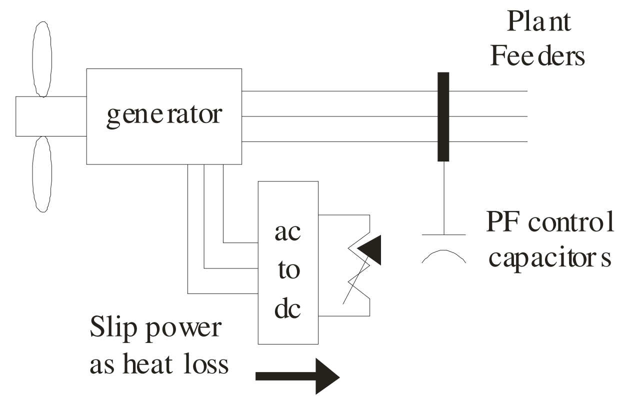
- **So far, real-time modeling efforts for wind power have concentrated on detailed modeling of individual turbines:**
  - Each of these turbines employs a generator, and has a power converter that switches at kilohertz frequencies
  - Model thus requires a very small time-step
- **For use in bulk power system simulations, individual turbine models can be computationally expensive:**
  - Regions typically contain numerous wind power plants
  - Each plant may contain hundreds of turbines
- **For the RTDS platform, the number of devices being modeled correlates strongly with the amount of simulation hardware required:**
  - Computationally expensive models translate to monetary expense
  - To enable simulation of large power networks on the RTDS, we propose the use of aggregate wind power plant models

Types of Wind Turbine Generators

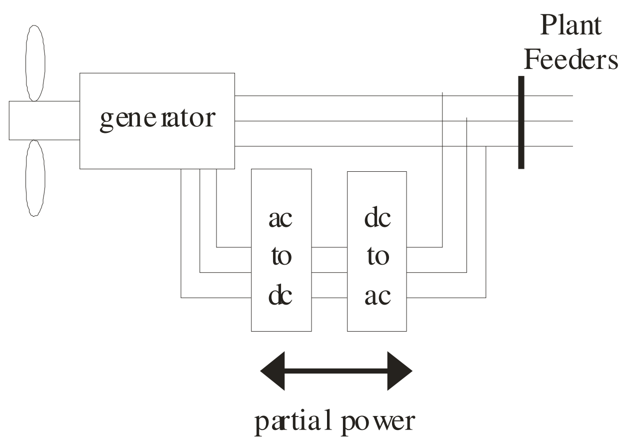
Type 1



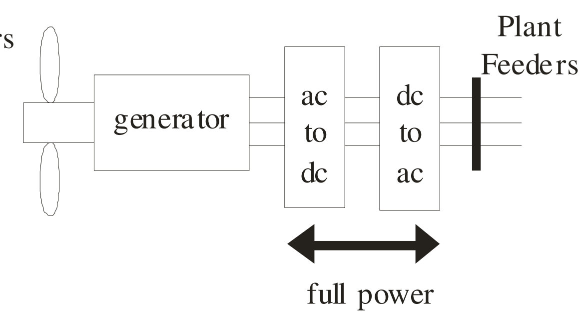
Type 2



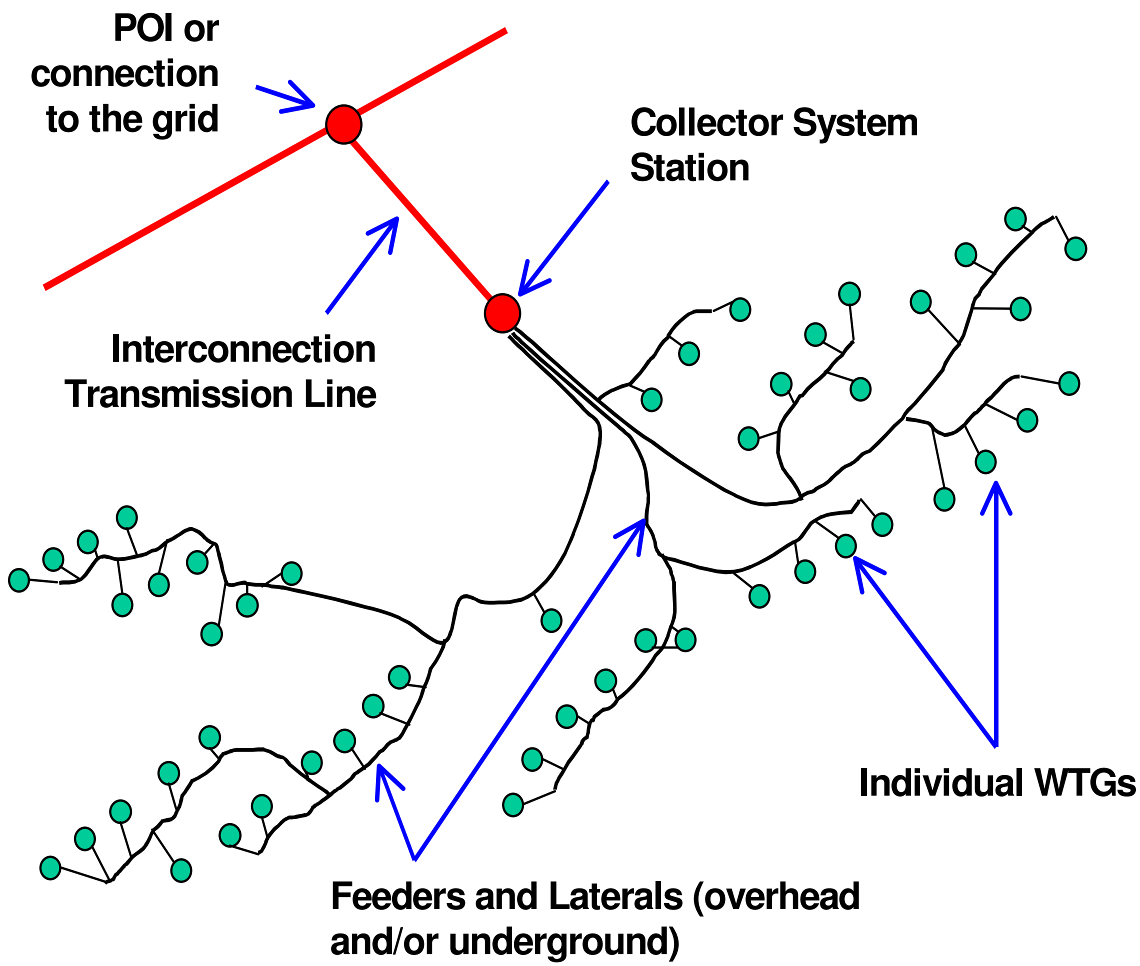
Type 3



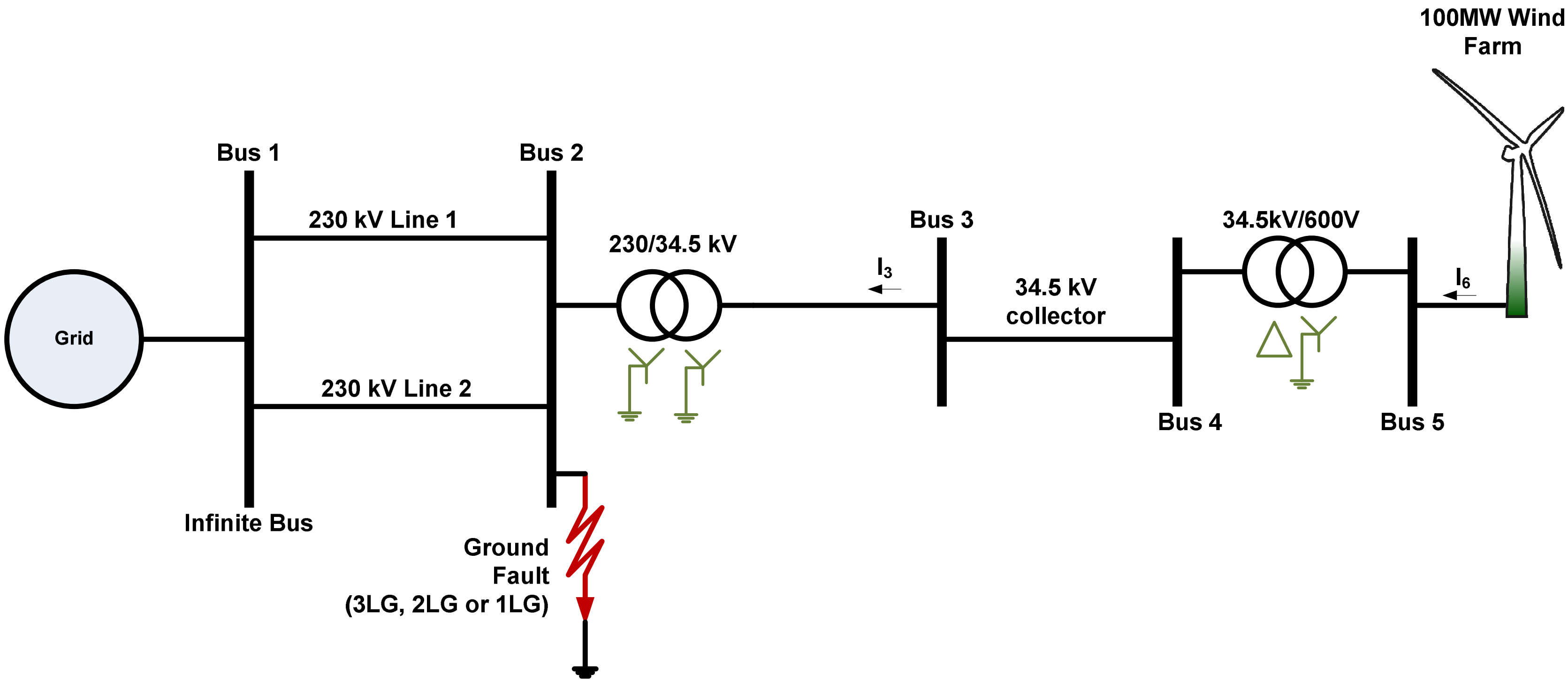
Type 4

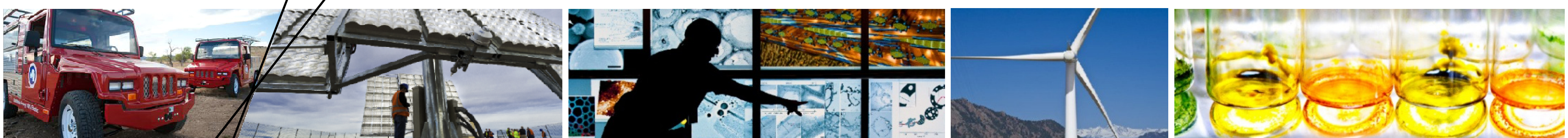


Physical diagram of a wind power plant



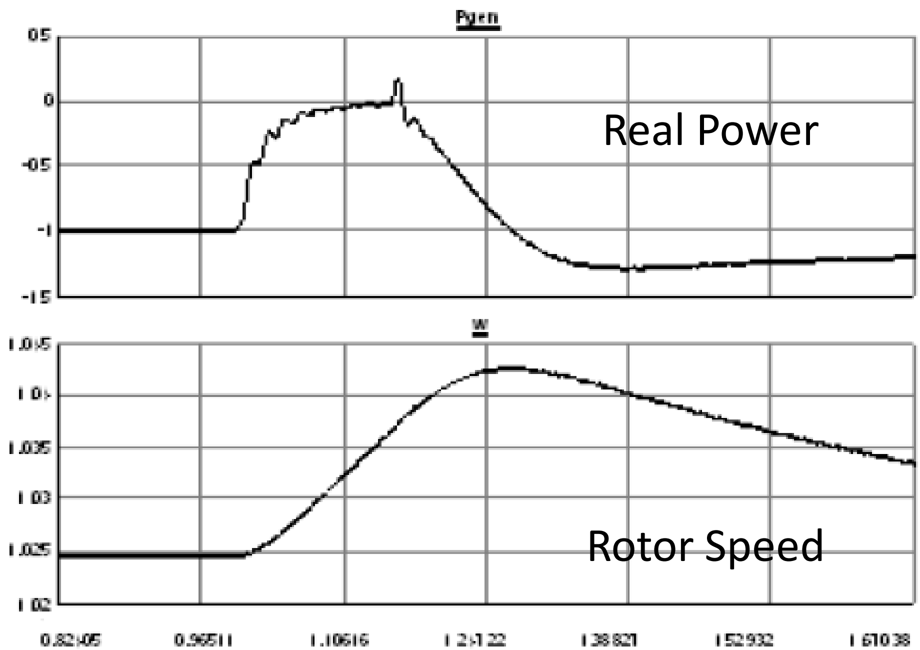
One-Line Representation of Power Plant

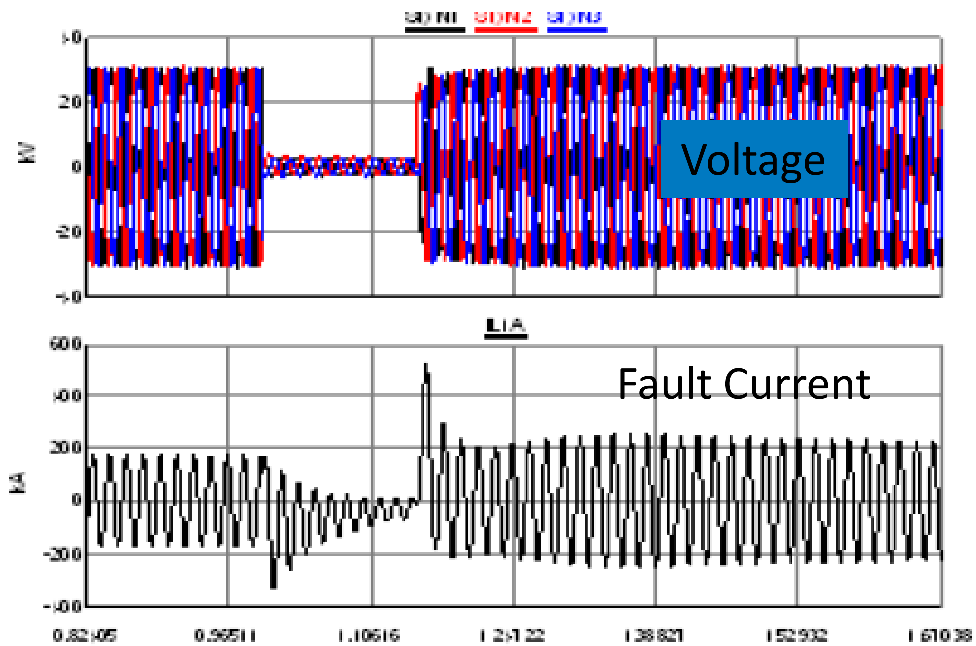




Results from Simulations

Type 1 Wind Turbine Generator: 3LG Fault

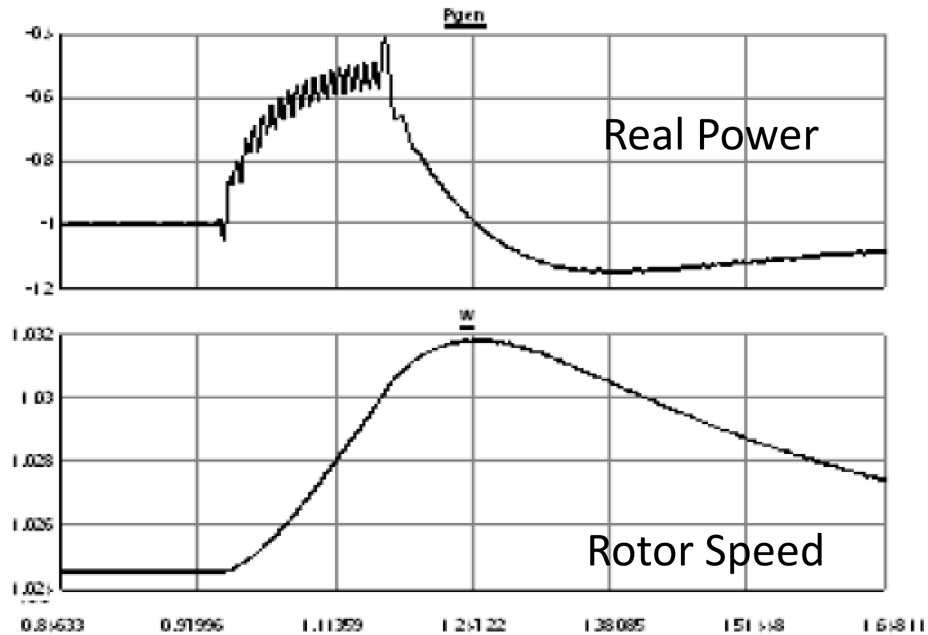


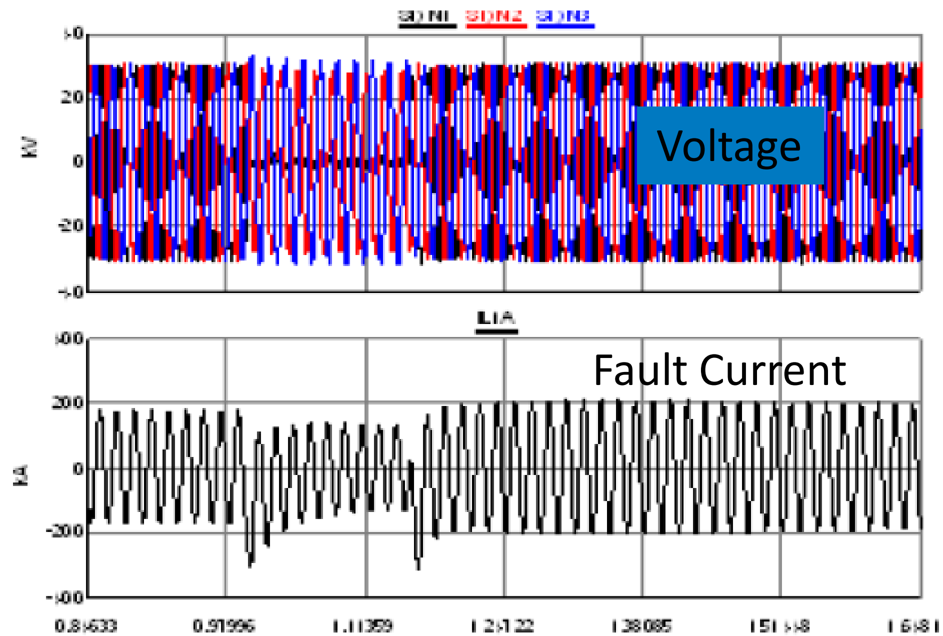


Fault causes real power to drop, thus, the aerodynamic power drives the rotor speed higher until fault is cleared.

The fault voltage drops to zero and the air gap flux dissipates and line currents dies out with the emf.

Type 1 WTG: Single Line to Ground (SLG)

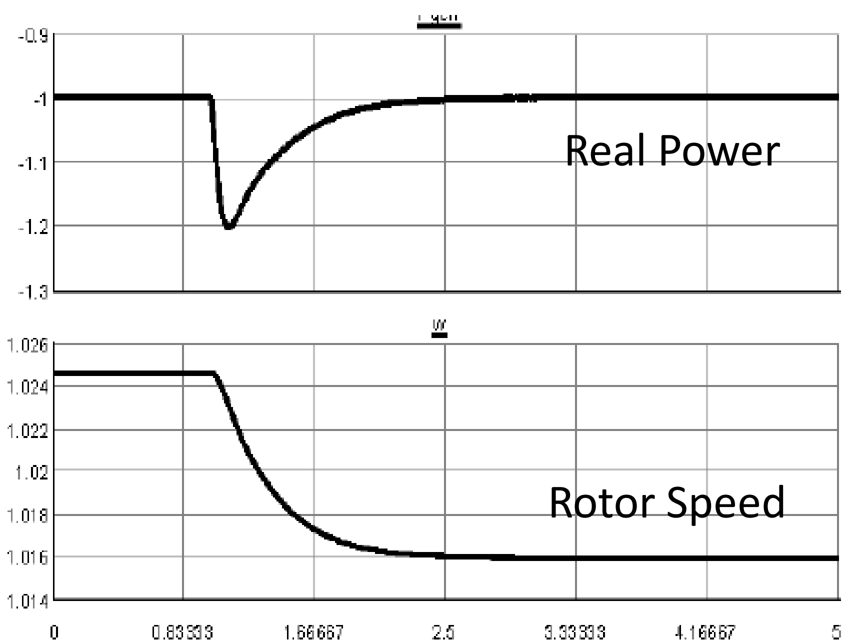




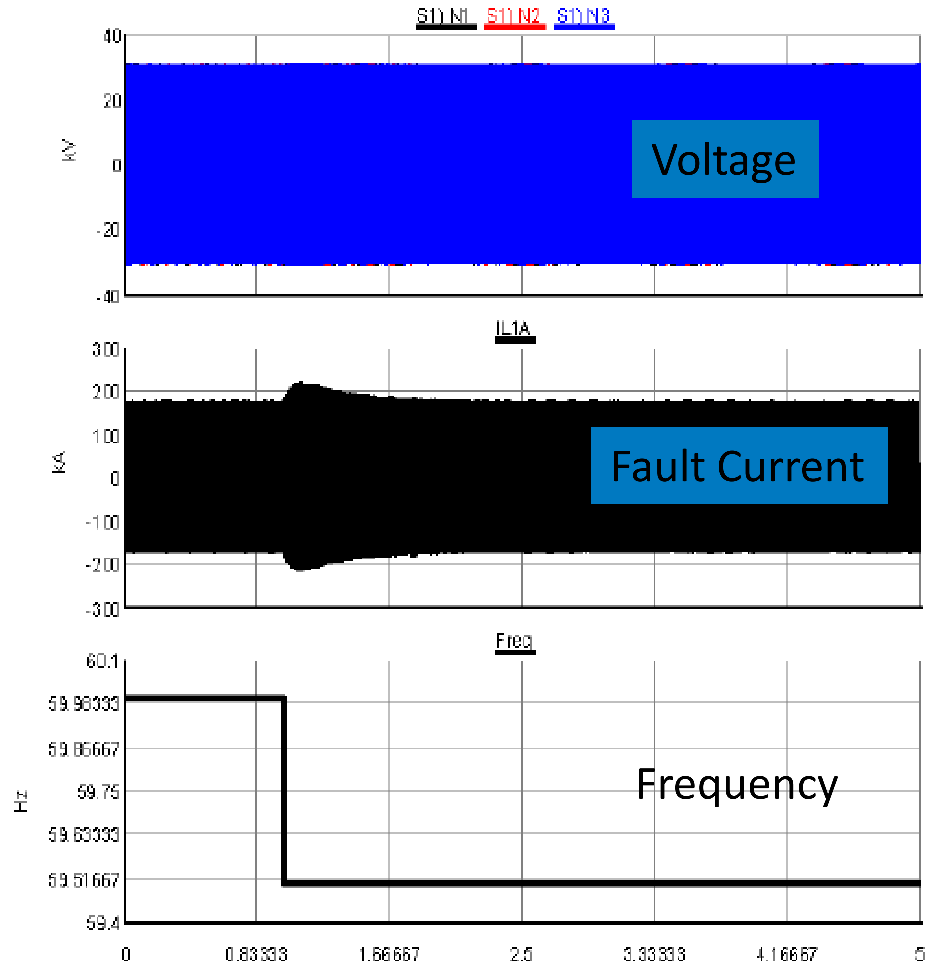
SLG Fault decreases real power output, thus, the aerodynamic power drives the rotor speed higher but not excessively

The normal phases drives the air gap flux, thus, sustaining the line currents during SLG Fault.

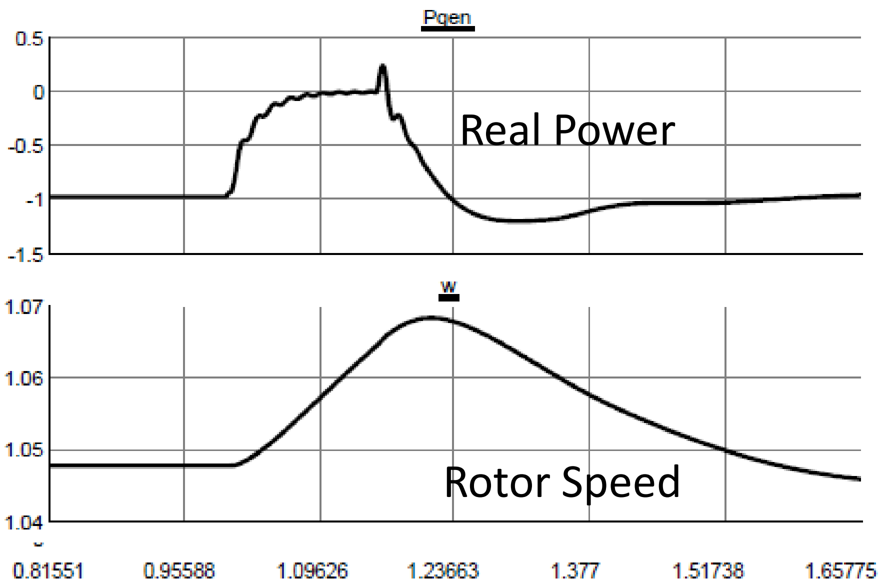
Type 1 WTG: Frequency Dip event

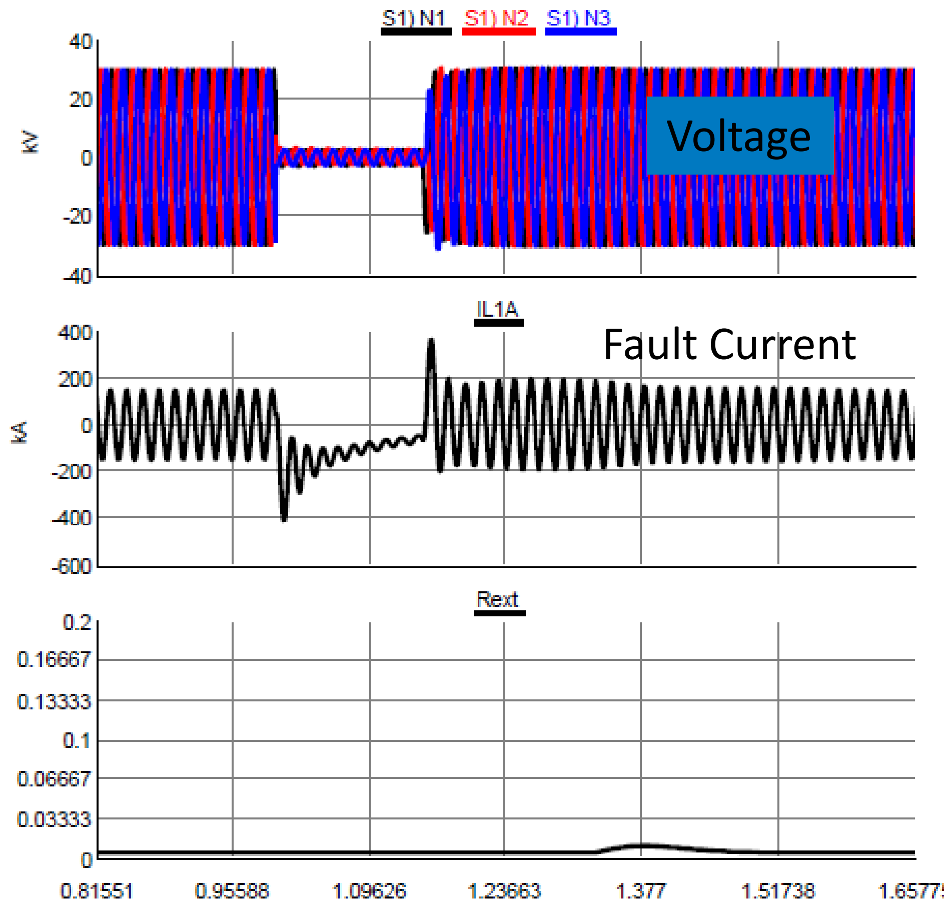


When the frequency drops, the slip increases due to lagging of rotor speed drop. Real power is shown to exhibit inertial response. Fault current has some modest increase.



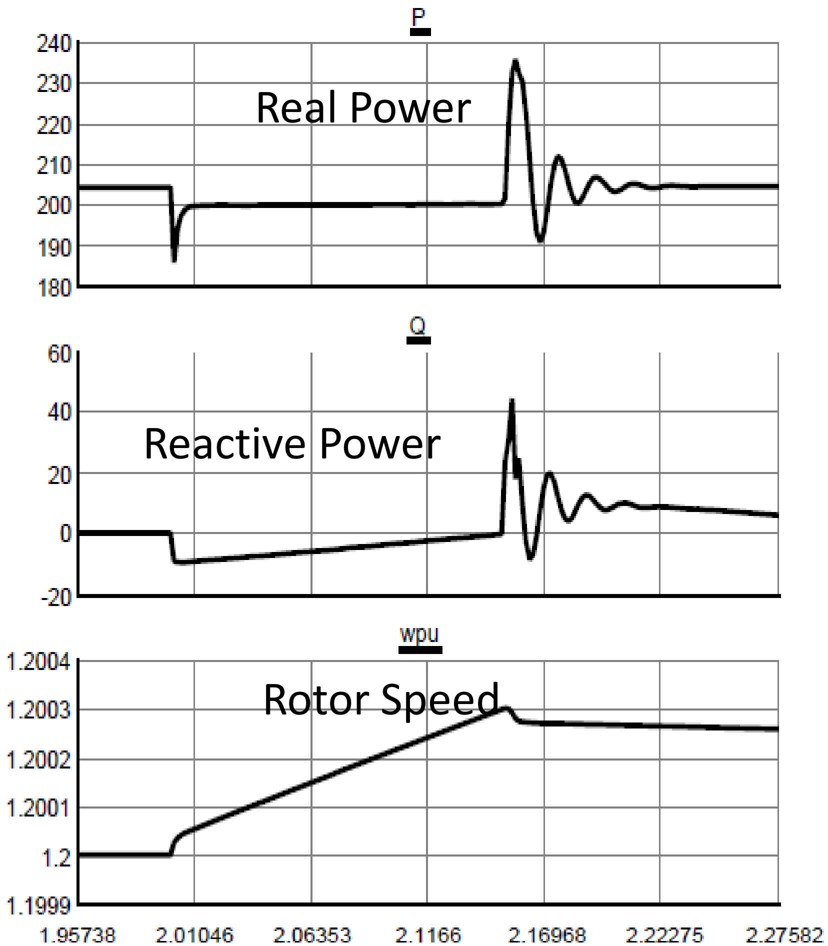
Type 2 WTG: 3LG Fault

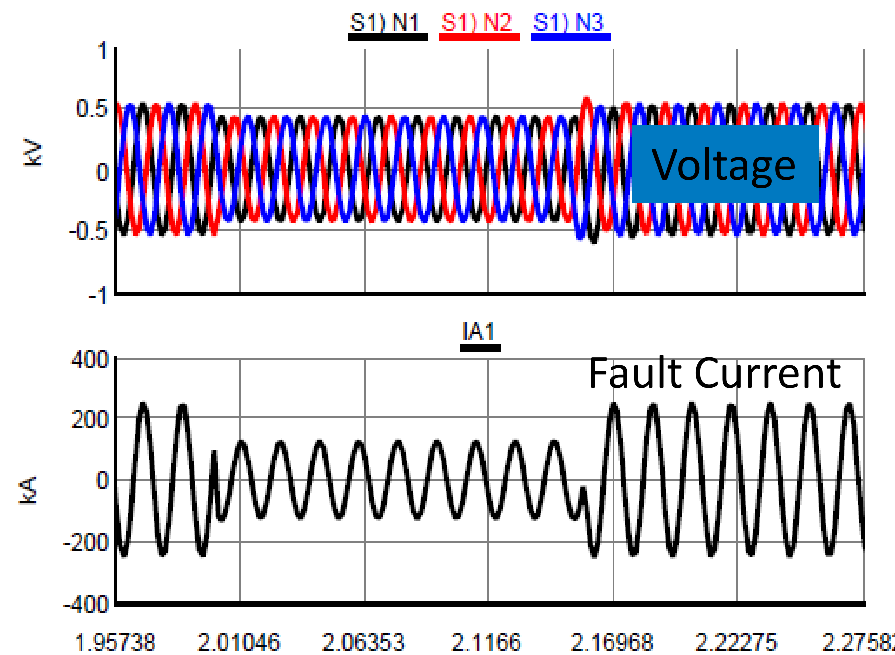




The power and rotor speed behavior is similar to type 1 WTG, but in the post transient, the external rotor resistance returns the output power and the rotor speed faster than type 2 WTG

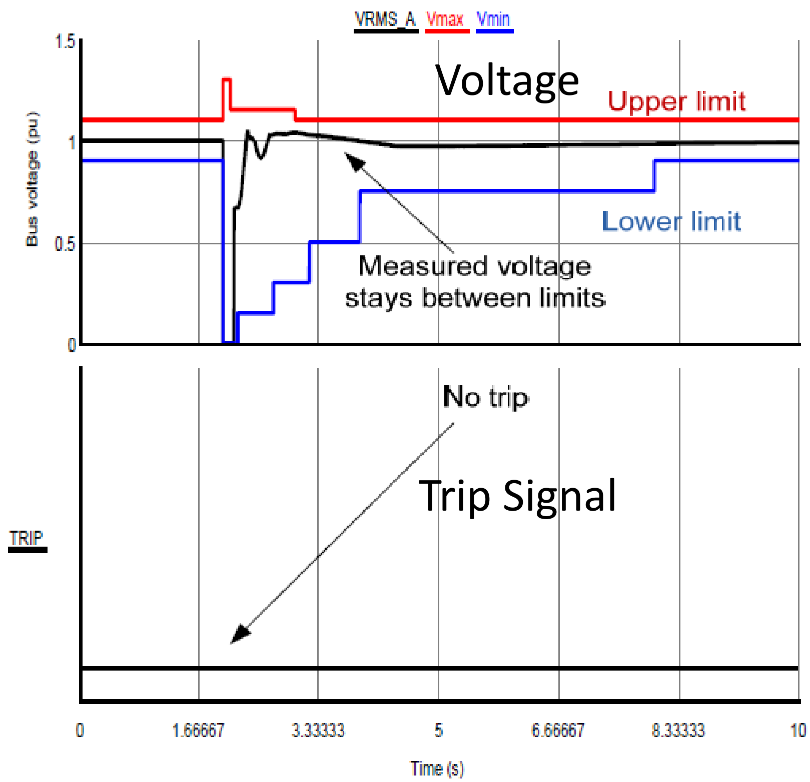
Type 3 WTG: 3LG Fault

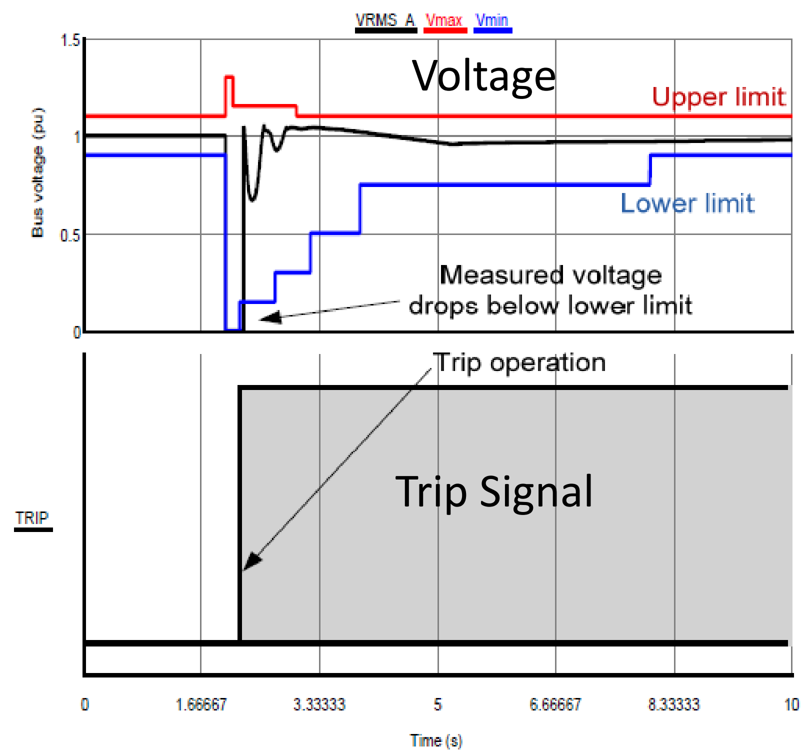




The output power decreases during the fault due to current limit of the converter maintaining rated current at reduced voltage, rotor speed increases, but was held by the pitch control. Reactive power tries to maintain the voltage.

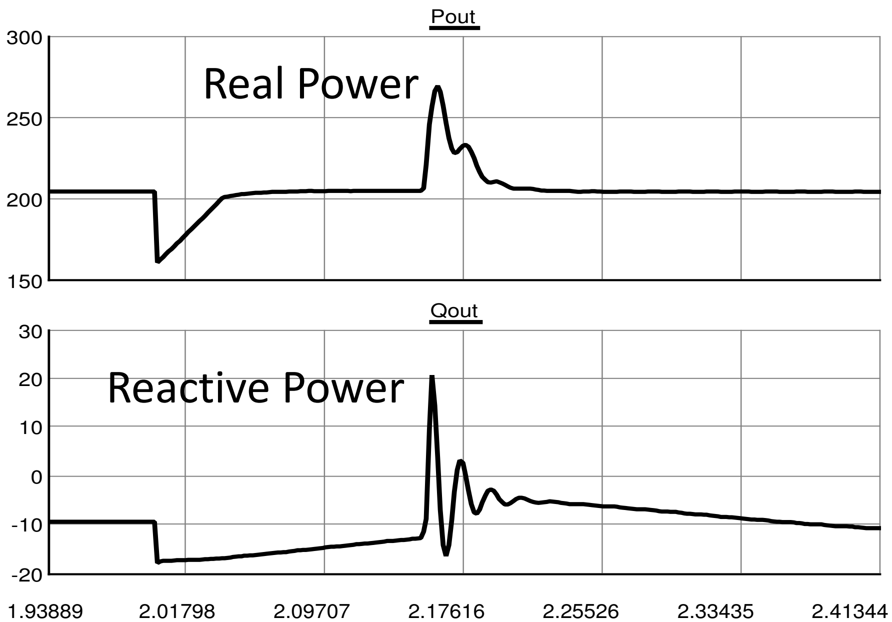
Type 3 WTG: Low Voltage Ride Through

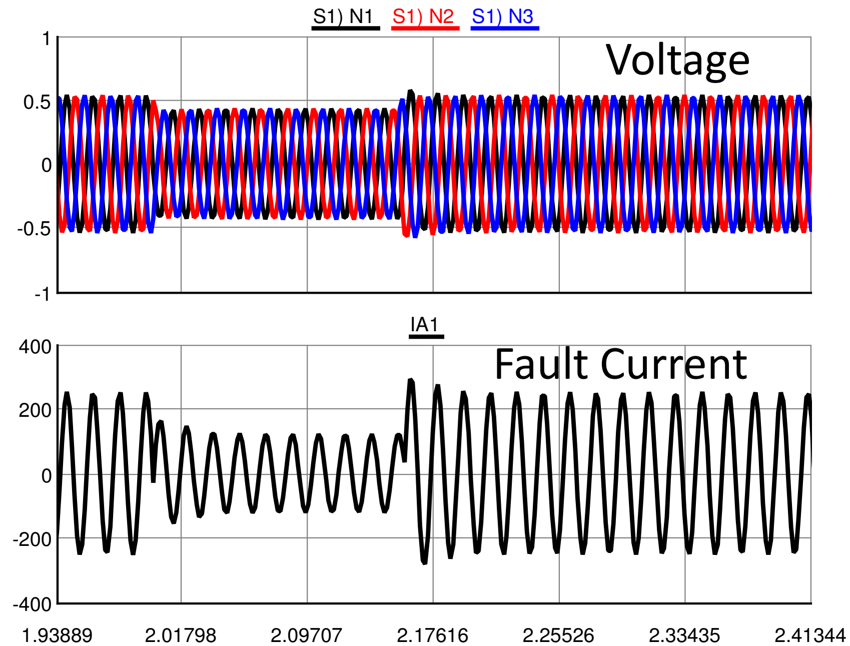




Relay protection is implemented for ride through capability. Note, when the fault is cleared < 9 cycles, the turbine can ride through. In comparison, as we delay the fault clearing (> 9 cycles), the turbine is allowed to trip.

Type 4 WTG: 3LG Fault





The output power decreases during the fault due to current limit of the contverter maintaining rated current at reduced voltage, rotor speed increases, but was held by the pitch control. Reactive power tries to maintain the voltage constant.

Summary

- **In summary, the results of RTDS simulations of four types of WPPs have been shown.**

- **The difference in response across WPP types has been explored:**
  - For Type 1 and Type 2 turbines, response to balanced and unbalanced faults has been examined
  - For Type 3 and Type 4 turbines, balanced faults and LVRT have been examined
  - Inertial response has also been examined for all types of turbines. (Type 1 response has been shown as an example.)

- These models are aggregate models of WPPs that retain enough fidelity to reproduce the dynamics of WPPs.
- These models can be incorporated into bulk power system models for large geographical regions built on the RTDS, where using single turbine models for each of the hundreds of turbines within the region would be infeasible or impractical.