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Validation of Dynamic Model of Wind Power Plants

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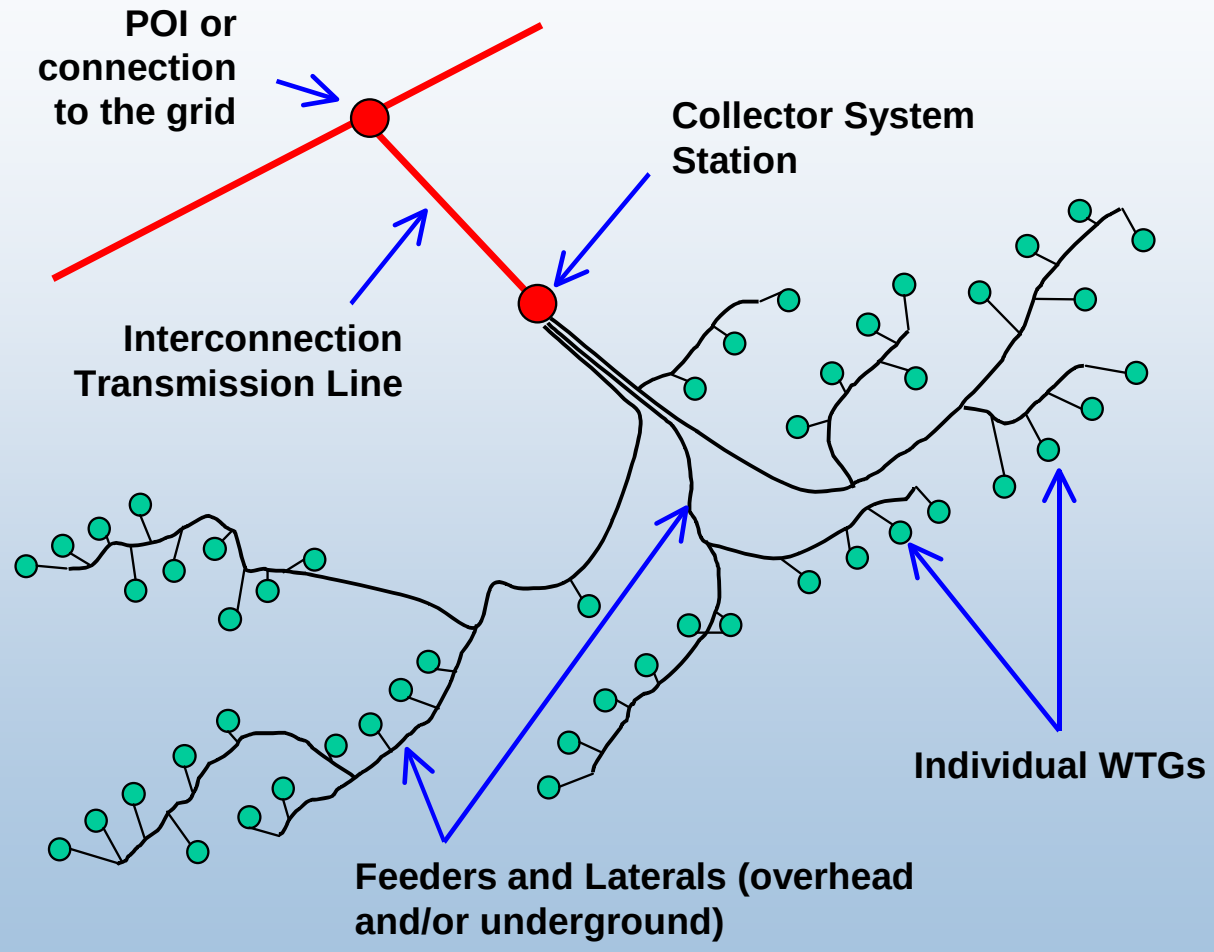
Dynamic Model Verification

- Two basic types, based on the transient nature of the event
  - Fault event
  - Switching event
- Data
  - Monitored data at the wind power plant (event triggered)
    - High speed data (time,V, I, P, Q, F)
  - Network data
  - Preprocessed data
- Model Equivalencing
- Case Study: Taiban Mesa

Simplified single-line diagram of a wind power plant



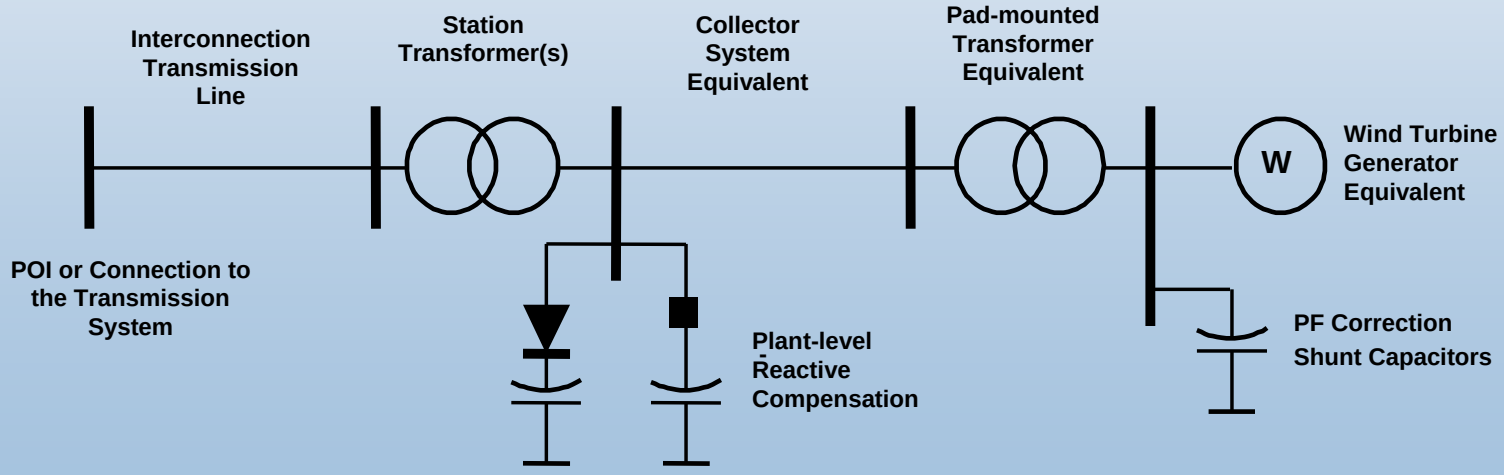
Single-machine equivalent representation

The major components equivalent representations:

• The equivalent generator and associated power factor correction capacitors represents the total output of all the WTGs in the WPP.

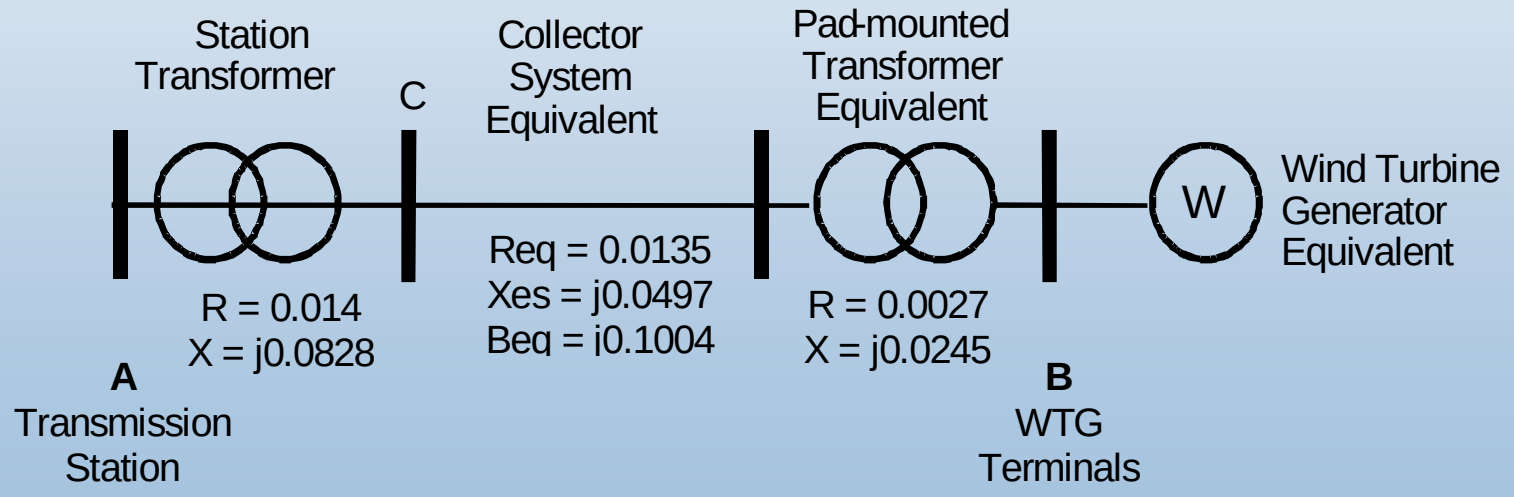
• The equivalent generator step-up transformer (pad-mounted transformer) represents the aggregate effect of all WTG step-up transformers

• The equivalent collector system branch represents the aggregate effect of the WPP collector system.



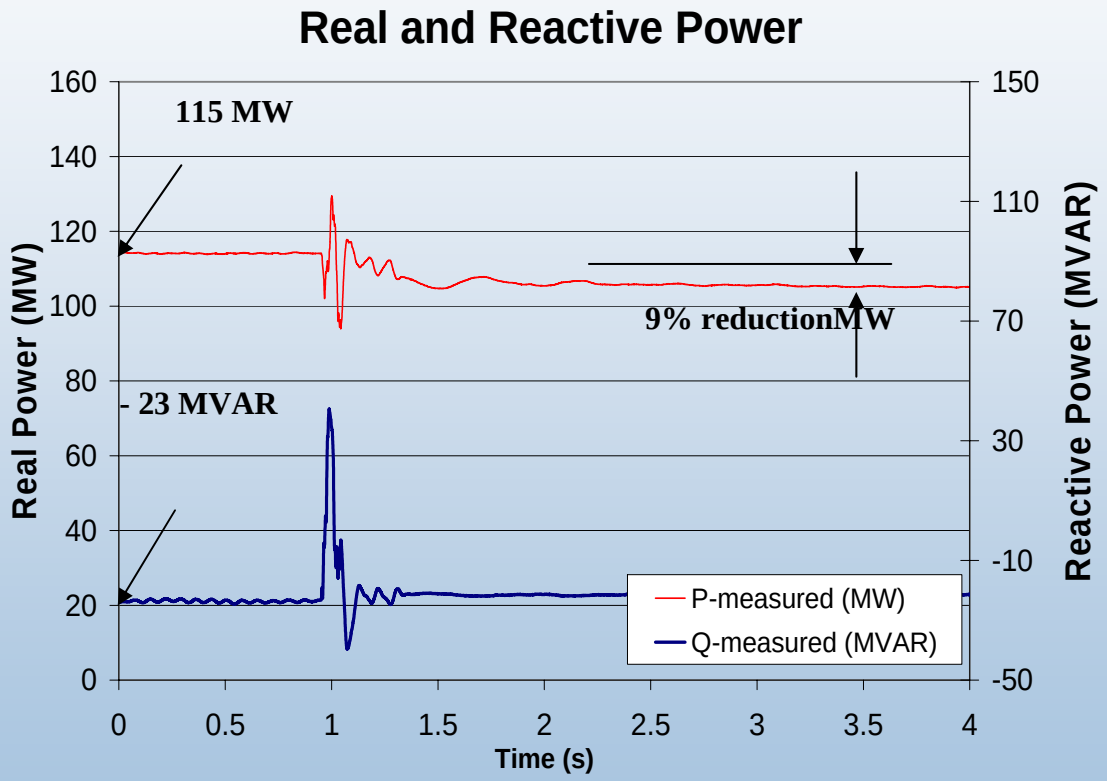
Load Flow – Steady State Initialization

- Set the bus A voltage to match recorded prefault voltage at bus A.
- Adjust WTG's P_{gen} to match the initial $P_{measured} = P_{simulated}$ =115 MW at bus A
- Adjust the regulated voltage V_{reg} at bus C to match the initial $Q_{measured} = Q_{simulated}$ = 23 MVAR at bus A



Wind Power Plant Data

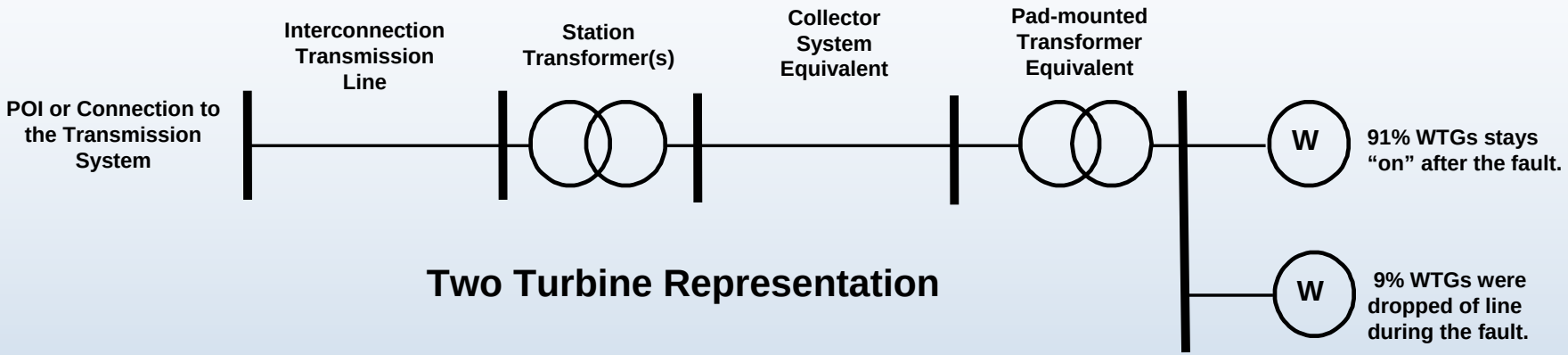
- Nature of the event: Fault event - single line to ground – 9 cycles
- 136 turbines – 204 MW rated
- V, I, recorded, P, Q, computed
- Method used: replay the voltage recorded and compare the PQ output
- Comparison of P, Q plots (recorded versus simulation data)
- Comparison: Measurement, Multiple Turbine Representation, Complete Model.



Real and reactive power measured at the POI.

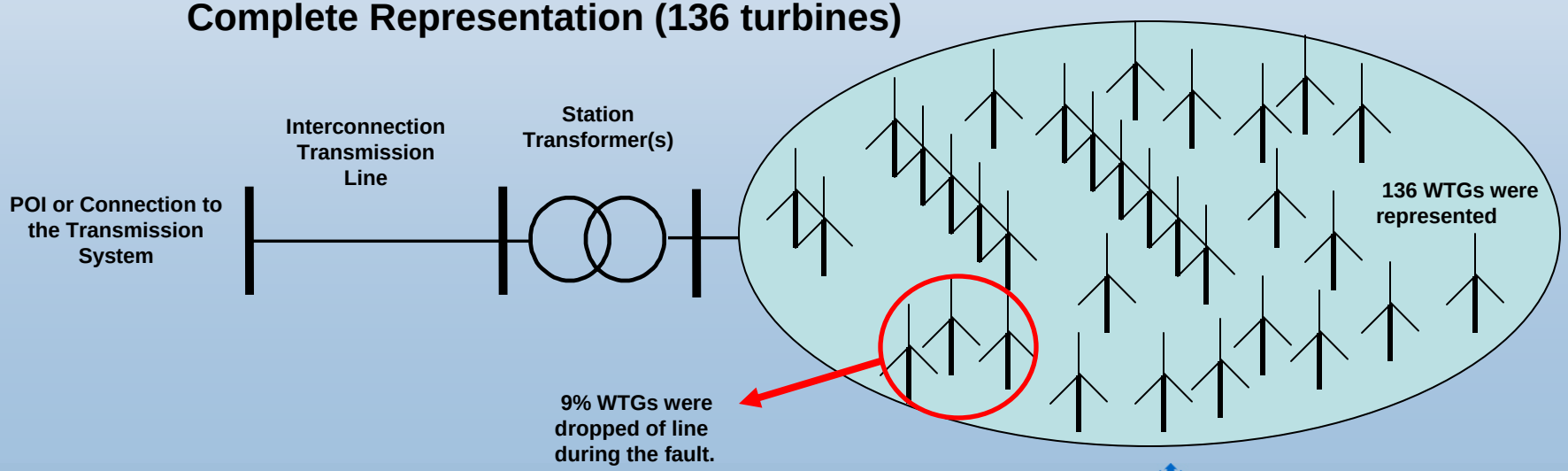
Event Representation

(Type 3 Wind Turbine Generator)

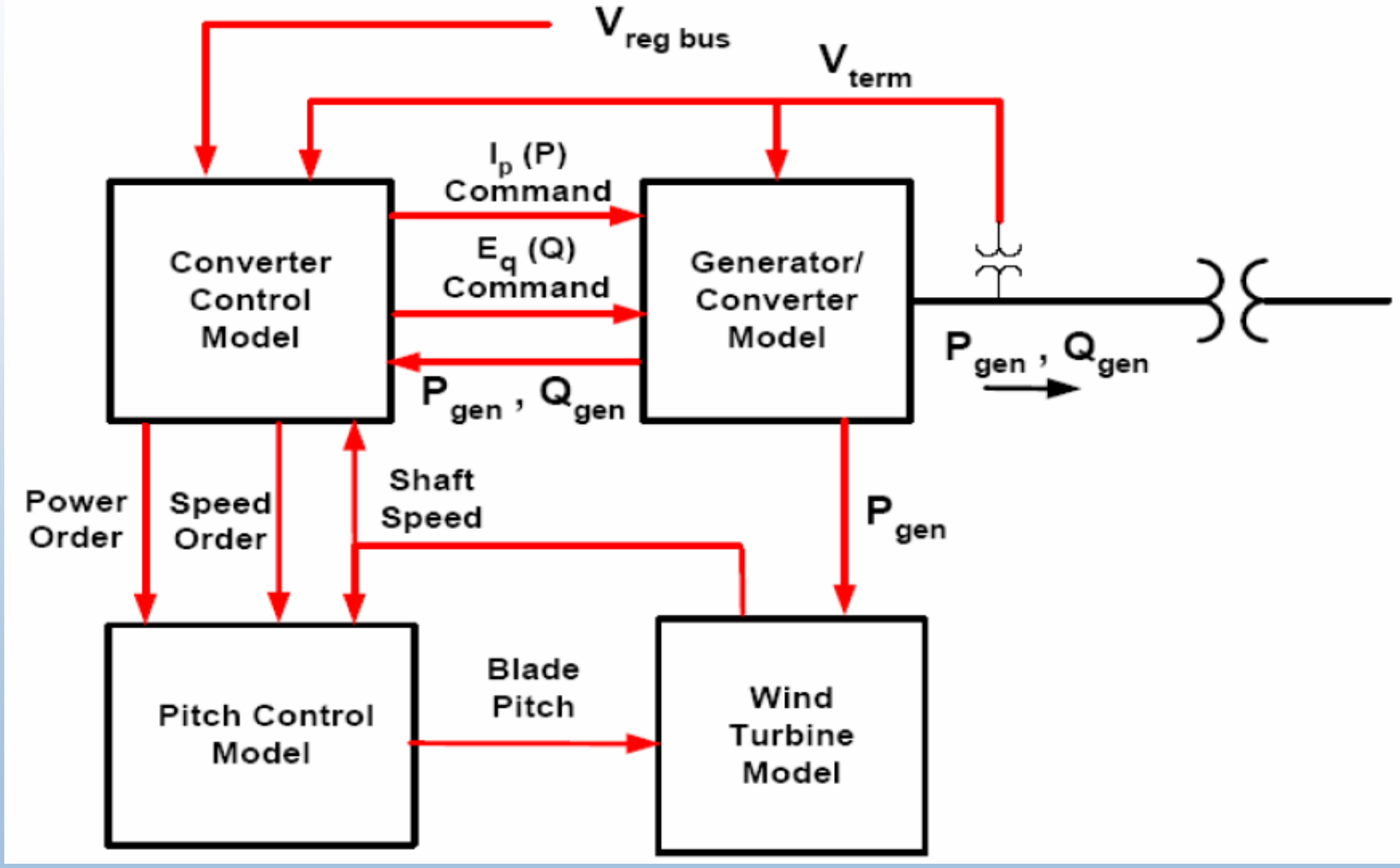


Two Turbine Representation

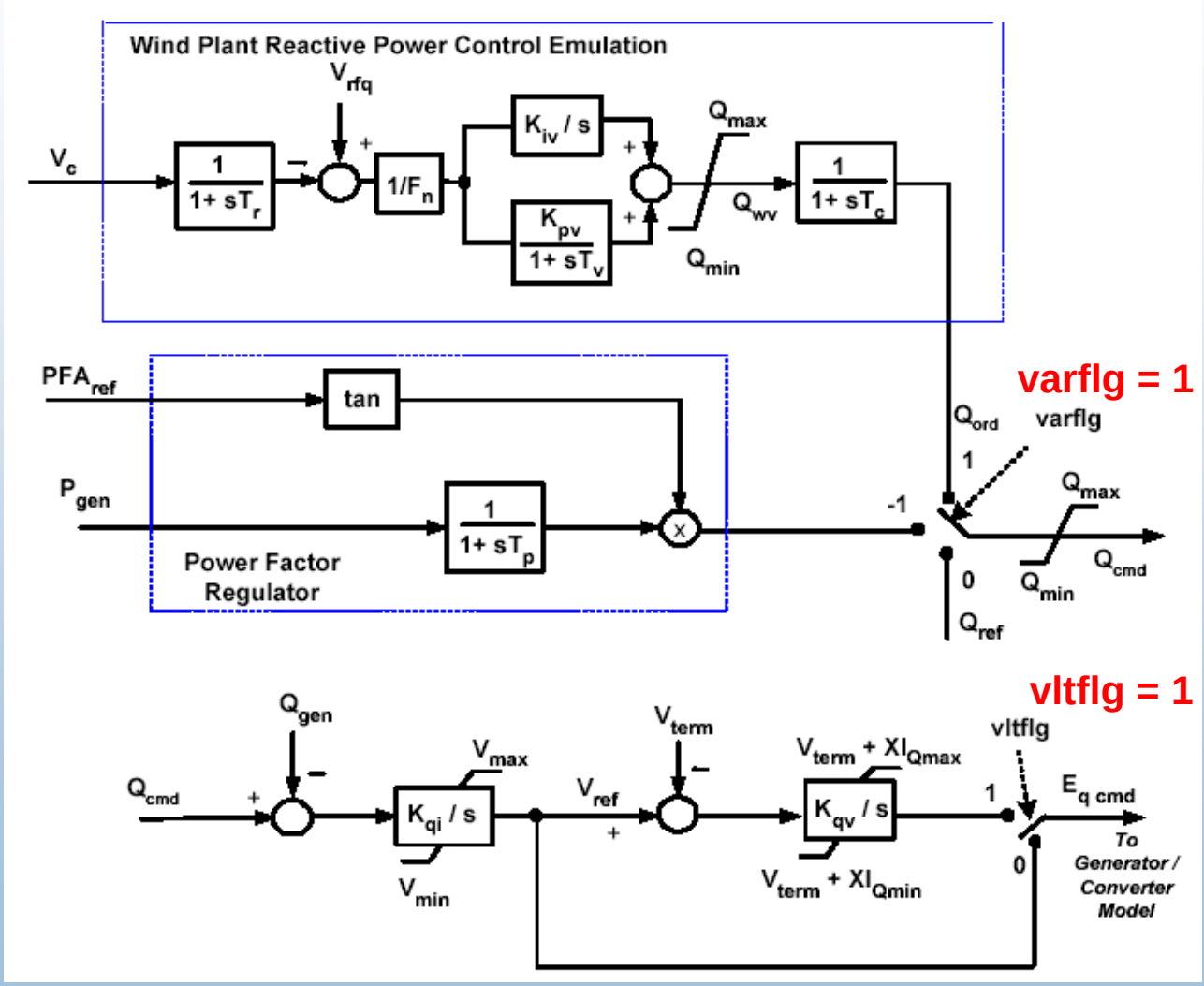
Complete Representation (136 turbines)



Block Diagram Type 3 WTG



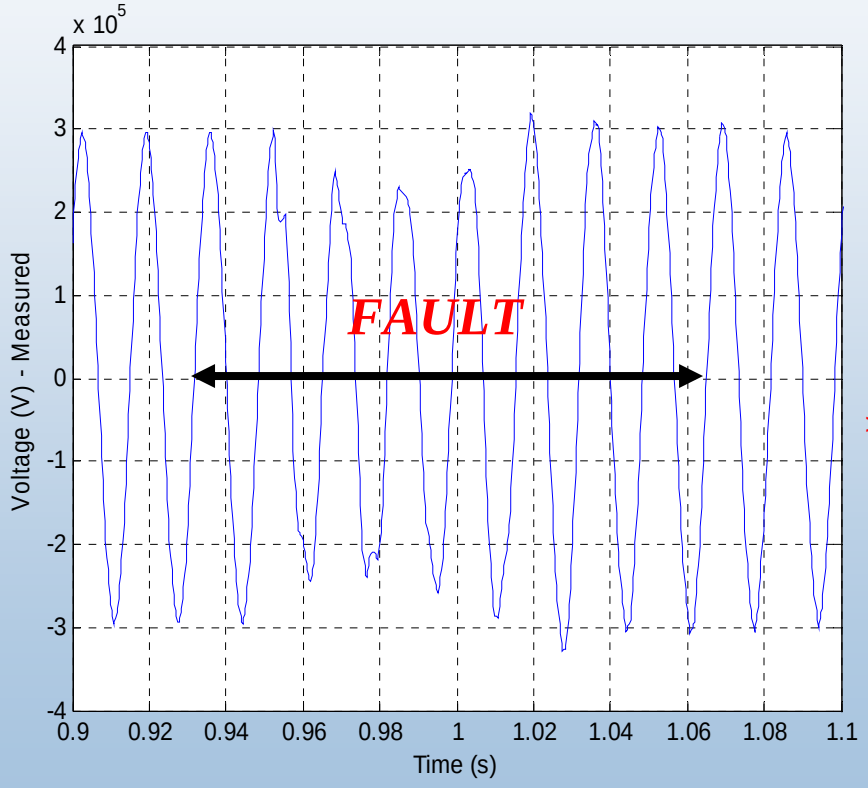
Reactive Power Control for Type 3 WTG



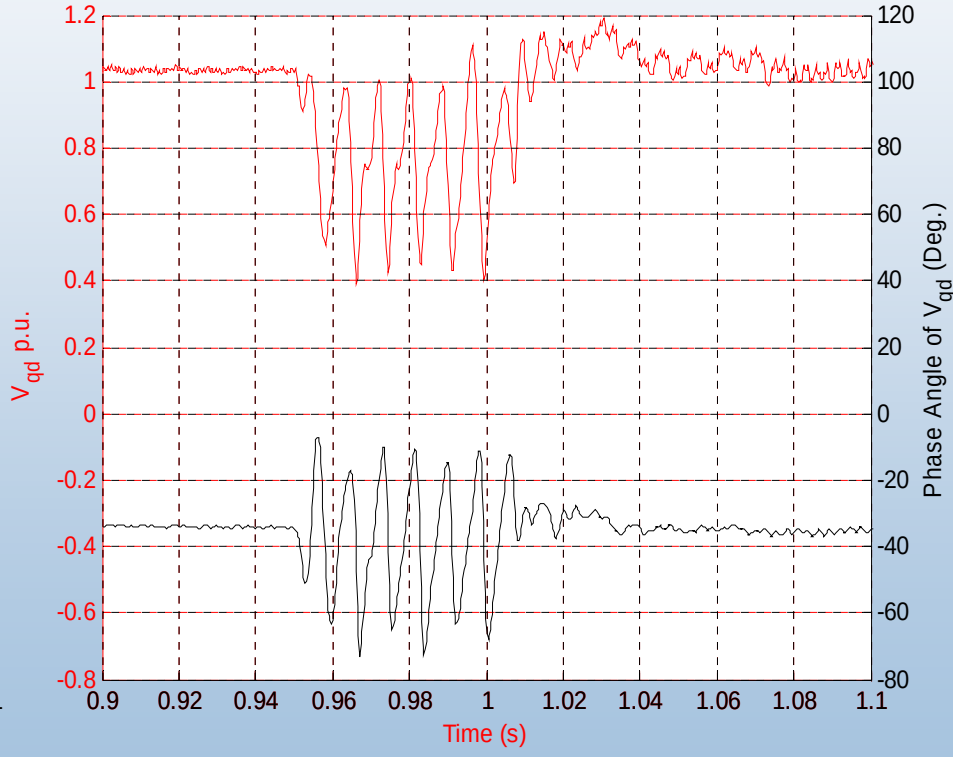
Sample of the Recorded Fault Data

(Instantaneous Voltage during fault event)

Instantaneous Voltage



Voltage and Phase Angle

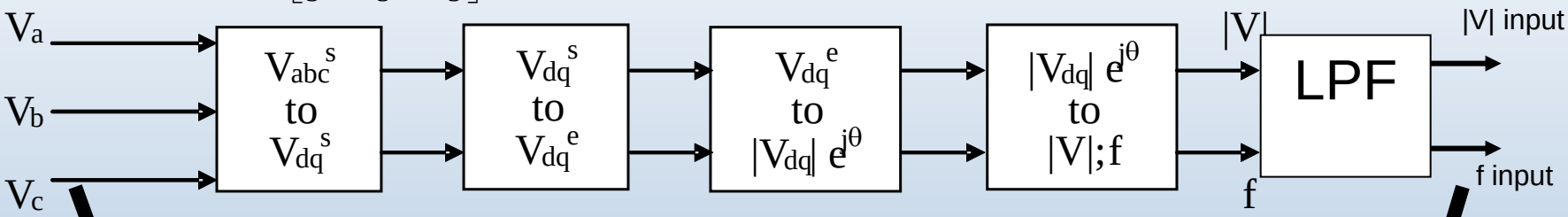


Data Conversion Process

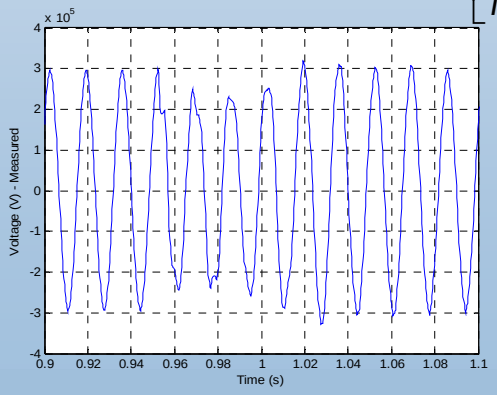
$$\begin{bmatrix} f_{qs} \\ f_{ds} \\ f_{os} \end{bmatrix} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & -\frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \begin{bmatrix} f_{as} \\ f_{bs} \\ f_{cs} \end{bmatrix}$$

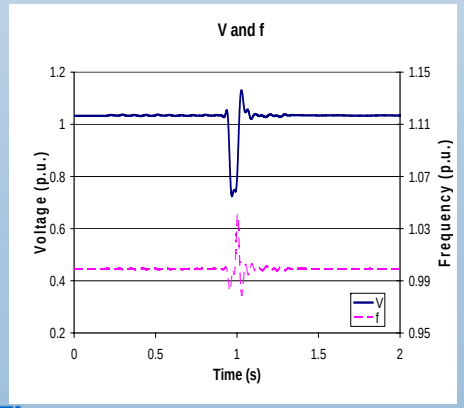
$$V_{qde} = \sqrt{V_{qe}^{\,2} + V_{de}^{\,2}} \angle \theta_{qde}$$

$$\theta_{qde} = \tan^{-1}\left(\frac{V_{de}}{V_{qe}}\right)$$

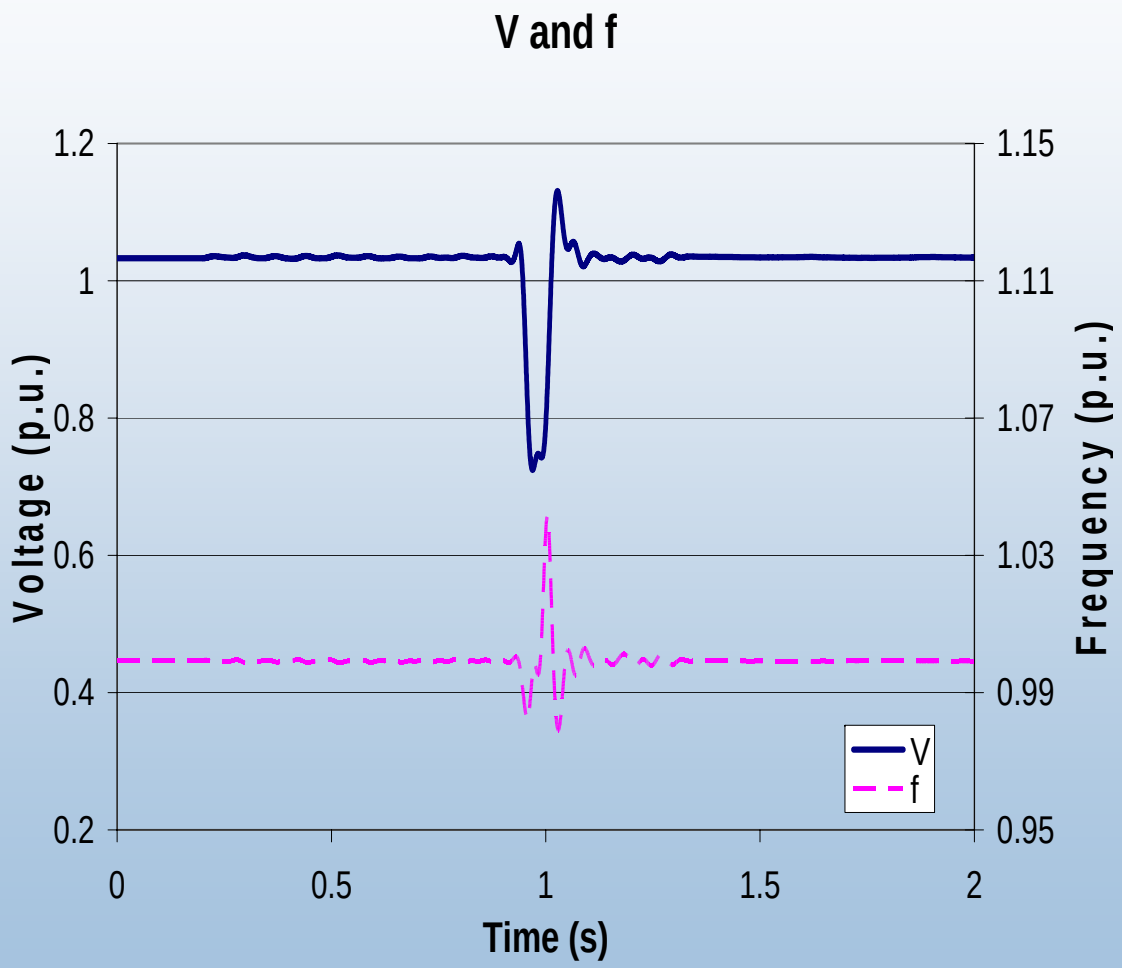


$$\begin{bmatrix} f_{qe} \\ f_{de} \\ f_{oe} \end{bmatrix} = \begin{bmatrix} \cos(\omega_e t + \theta_o) & -\sin(\omega_e t + \theta_o) & 1 \\ \sin(\omega_e t + \theta_o) & \cos(\omega_e t + \theta_o) & 1 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} f_{qs} \\ f_{ds} \\ f_{os} \end{bmatrix}$$



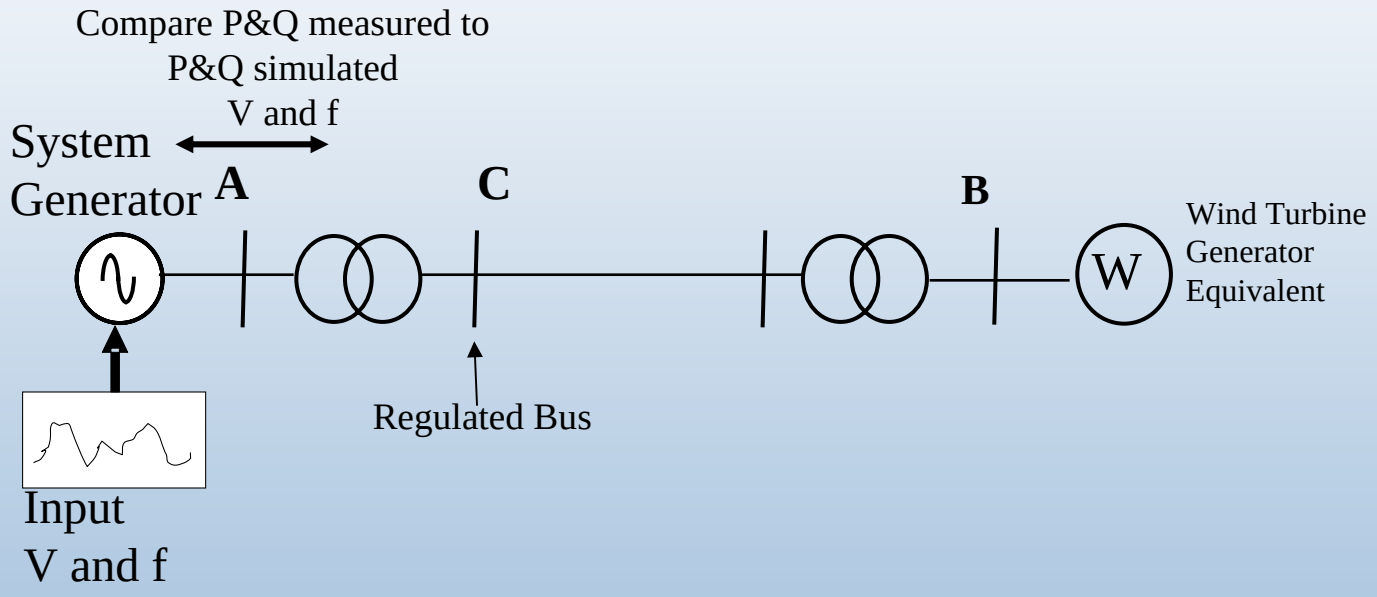


Voltage and Frequency

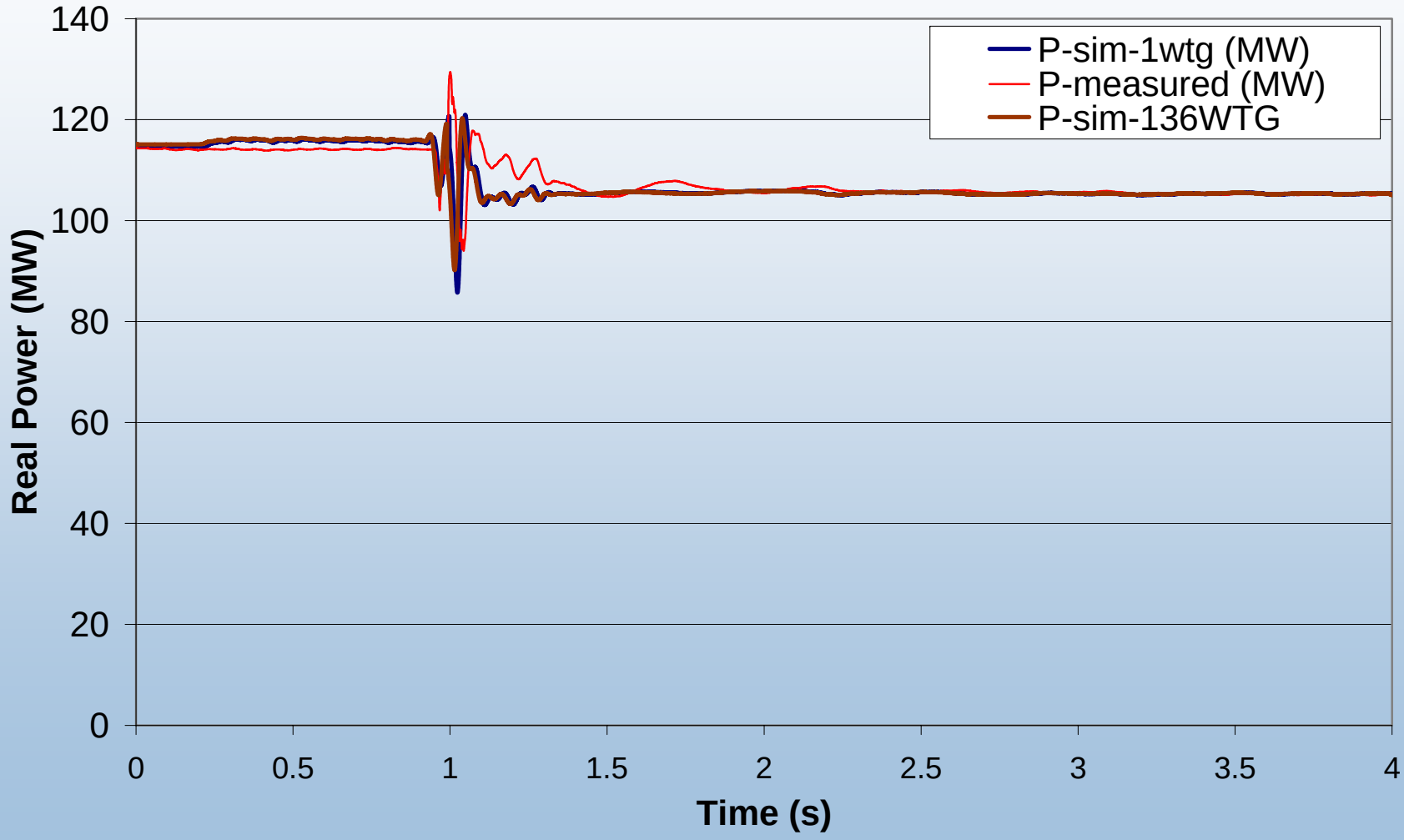


Voltage and frequency used as input to drive the simulation

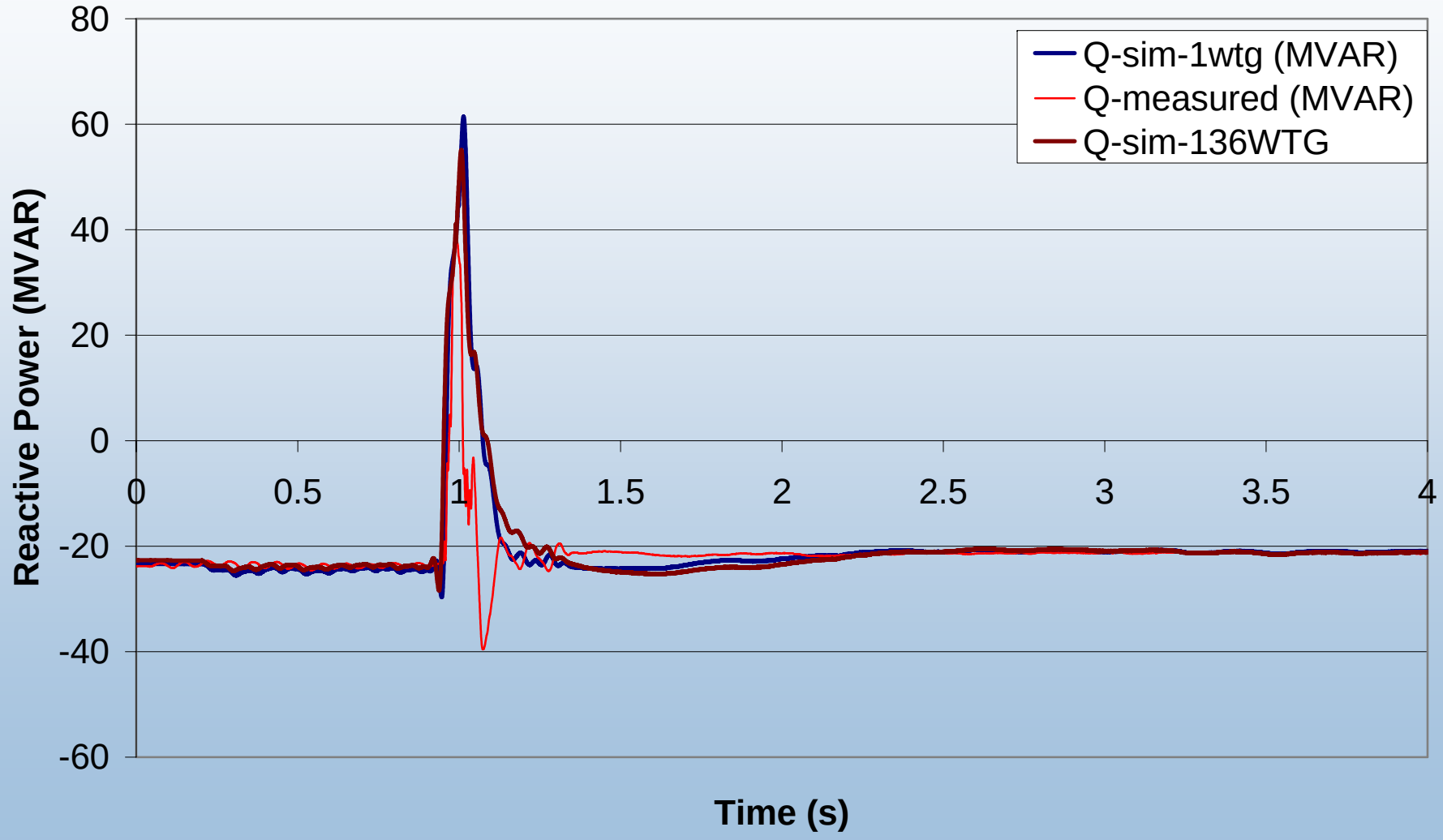
Validation Technique



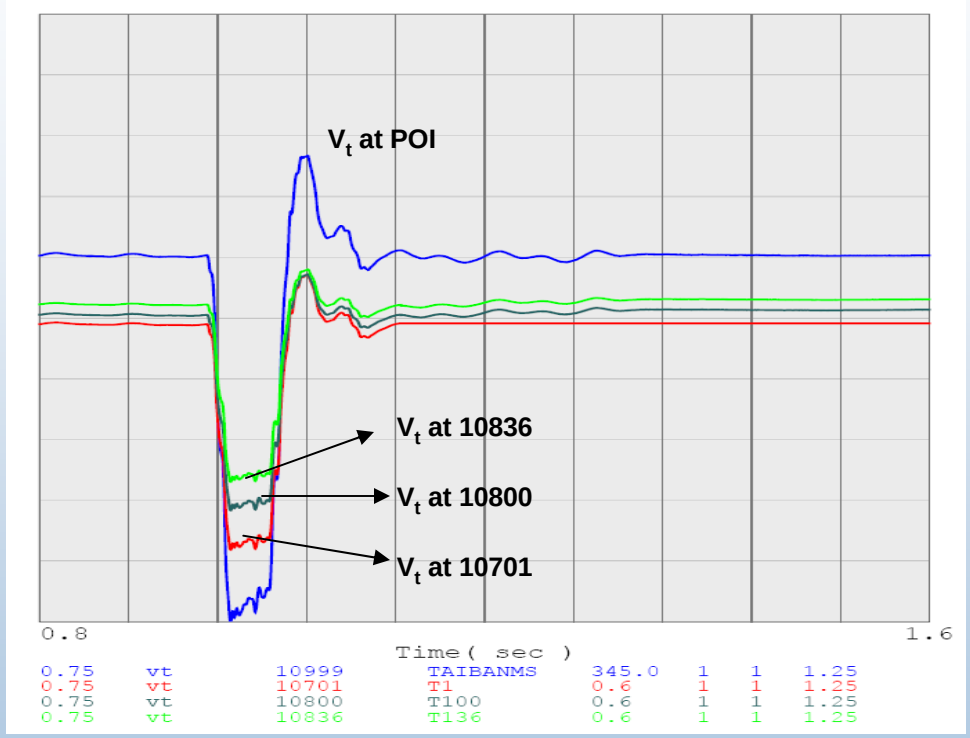
Real Power Comparison



Reactive Power Comparison



136 Wind Turbine Simulation



Voltages at different WTGs in per unit.

Conclusions

- This paper presents the methods to validate positive-sequence wind dynamic models. This technique was applied to the WECC generic model as an example.

- The validation method described in this paper is applicable for all the four types of wind turbine generators.

- The preliminary results of the simulations demonstrated that a generic model of DFIG generators provides an adequate representation of the actual wind turbines under fault conditions.

- It is also shown that modeling the wind power plant with an equivalent representation preserves the basic response of the wind power plant.