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Development of an Interface for Hybrid Simulation Studies Using TSAT and RTDS

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Conventional Simulation Methods

- System dynamics are conventionally divided into low- and high-frequency transients
- Two groups of industrial-grade tools have been developed based on this categorization

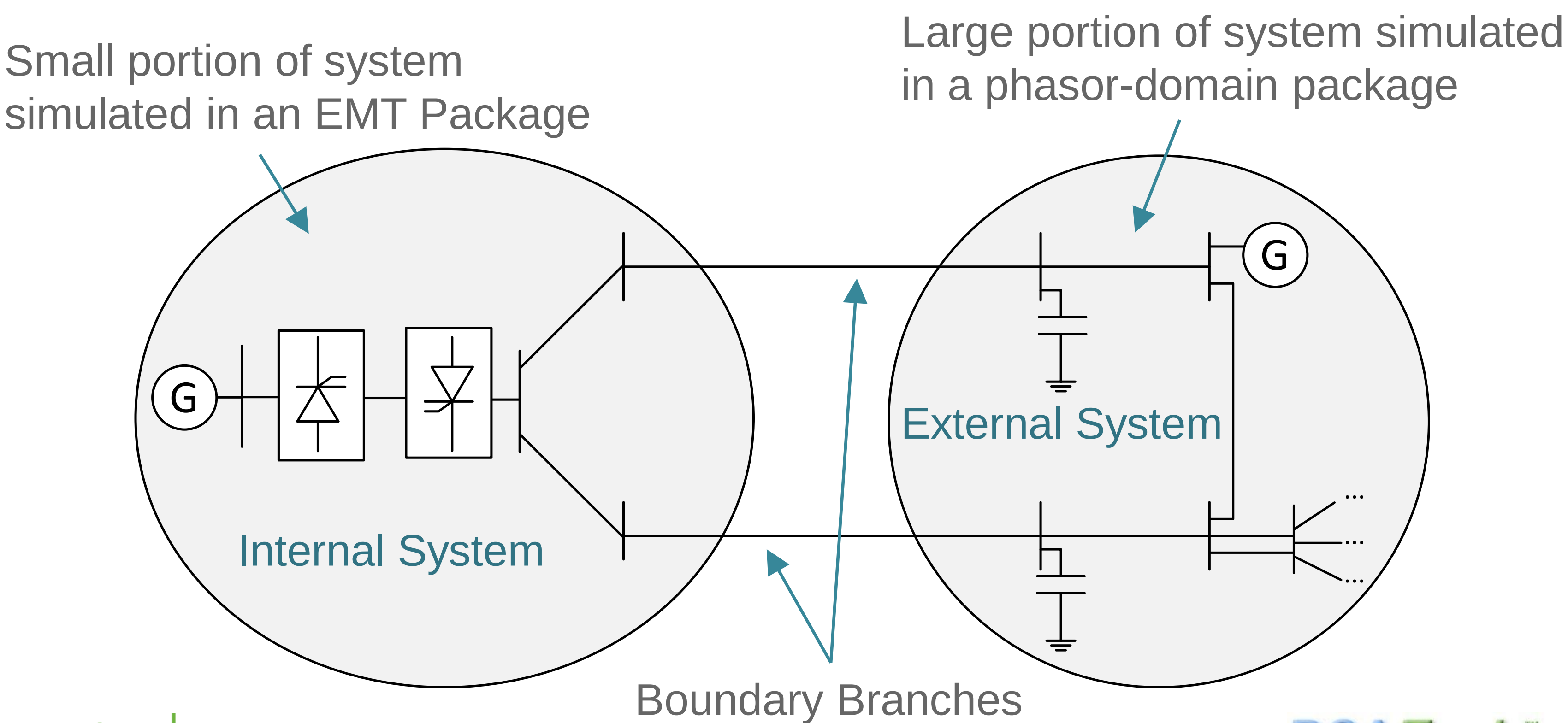
Feature	Electro-Magnetic Transients	Phasor-Domain
Sample Programs	RTDS, PSCAD	TSAT, PSS/E, PSLF
Level of details	✓ Three-phase ✓ Components modeled in details	✓ Phasor-domain ✓ Simplified dynamic models ✓ Network dynamics ignored
Size of system	✓ Depends on available computational hardware ✓ Varies between a few to several hundreds of buses	✓ Can simulate systems with several tens of thousands of buses
Common Application	✓ Any type of study that needs detailed modeling	✓ Bulk power system planning and operation

Challenges Related to Conventional Simulation Methods

- Can focus on either detailed models in small system or simplified models in large system
  - Increasing level of details without reducing system size can be costly
- Studying interactions between system-wide events and detailed devices can be challenging, e.g.
  - Fault analysis in HVDC systems
  - Subsynchronous resonance studies
- A detailed model might be available only in an EMT package, e.g.
  - HVDC systems, renewable generators, FACTS devices, etc.

Hybrid Simulation

- Hybrid simulation approach addresses these challenges by using both EMT- and phasor-domain simulation methods



Advantages of Hybrid Simulation

- Effective in analyzing impact of low-frequency oscillations on specific components and vice-versa

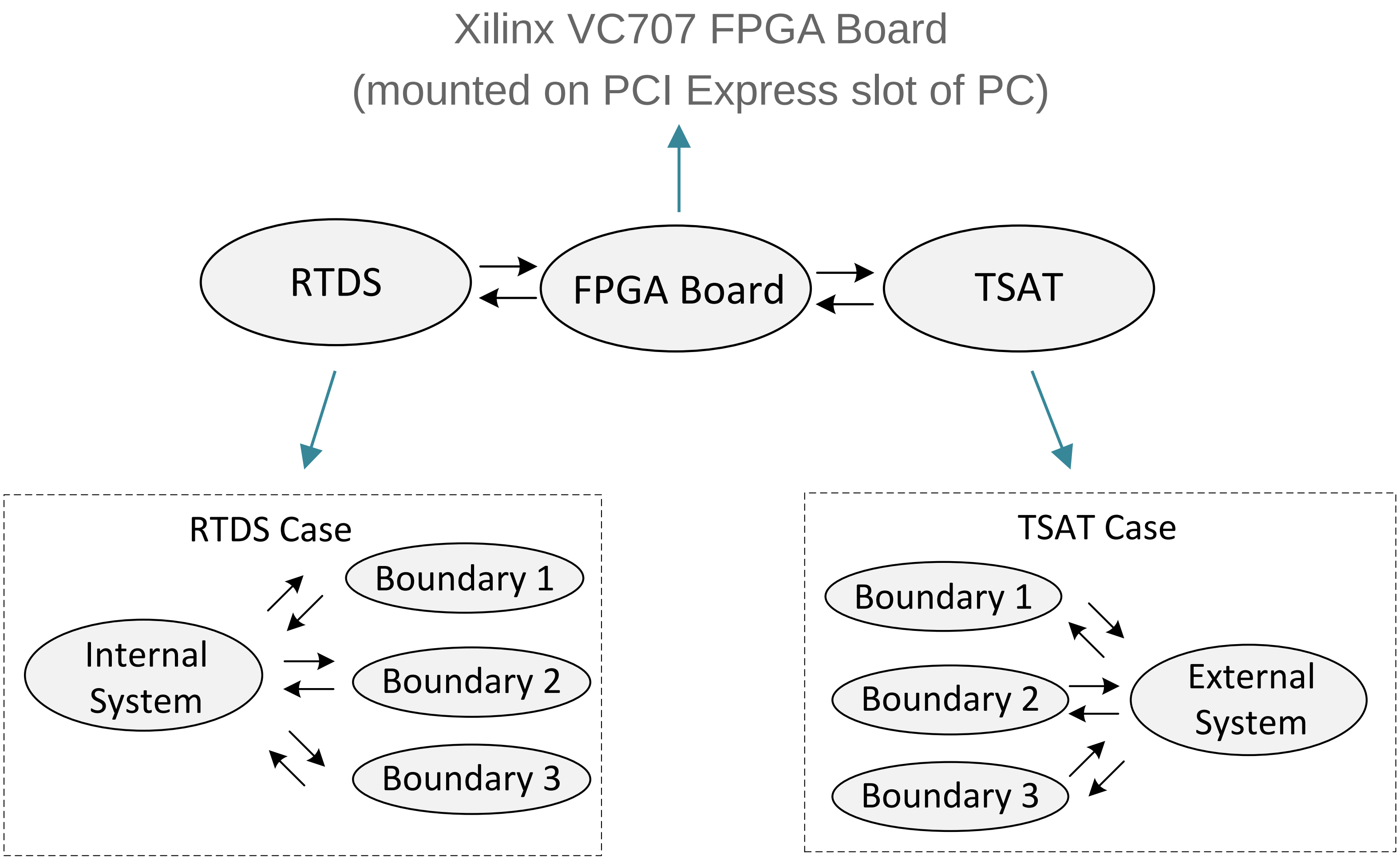
- A cheaper solution for studying large systems compared to full-EMT simulation

- Takes advantage of rich modeling library available in EMT and phasor-domain simulation packages

TSAT-RTDS Interface (TRI)

- A tool for performing hybrid simulation studies
  - Small part of system modeled in RTDS, rest of system modeled in TSAT
  - Developed by Powertech
  - With participation of Yonsei University
  - Sponsored by KEPRI
- TRI is developed with special focus on **practical aspects** to
  - Make the tool user-friendly
  - Minimize case setup efforts
  - Simplify results analysis steps

TRI Structure



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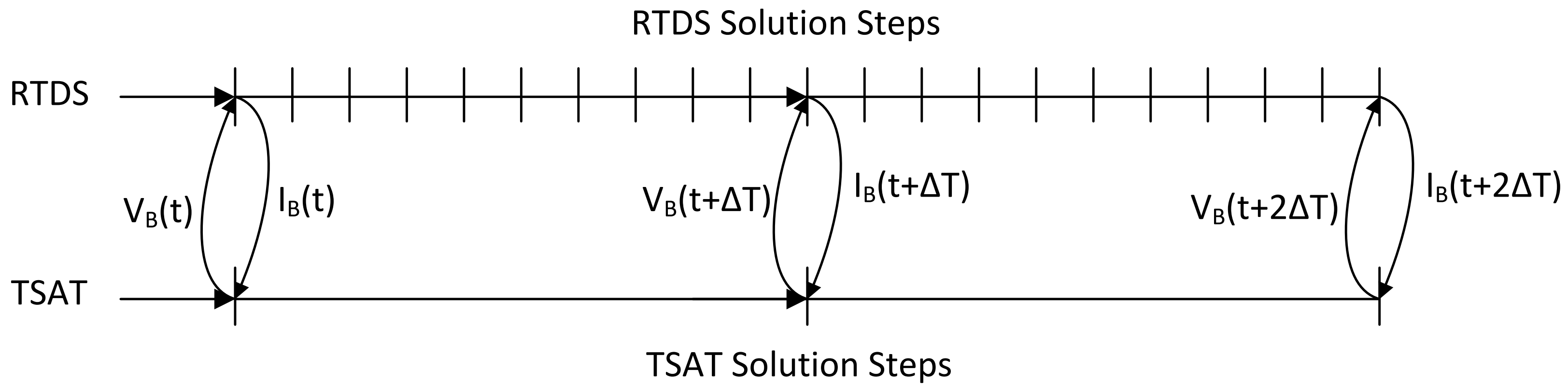
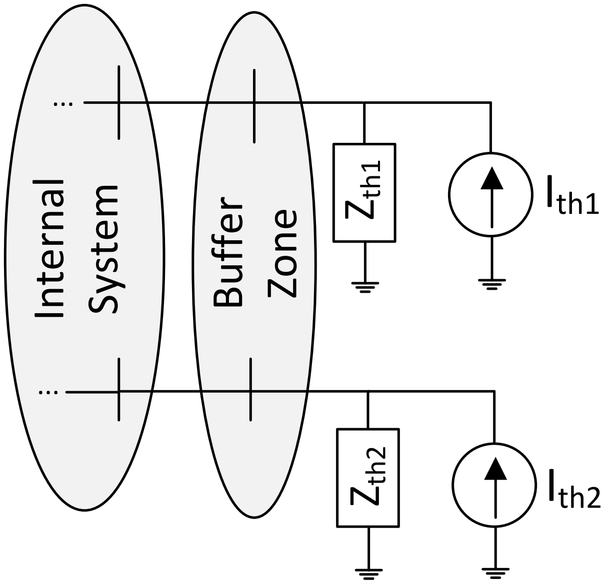
How Does TRI Works?

- RTDS simulates internal system at normal time-step (e.g. 50us)
- TSAT simulates external system at normal time-step (e.g. 5ms)
- Boundary injections are exchanged at the end of every TSAT integration step



Representation of External System in EMT

- Approach 1 – Norton (or Thevenin) Equivalent
  - External system is modeled as a Norton equivalent
  - ✓ Easy-to-use since TSAT automatically
    - calculates Thevenin impedance
    - updates Norton source current
  - ✘ May fail when fault is applied at boundary
  - ✘ A buffer zone between internal and external systems is recommended



Modeling External System in Internal System

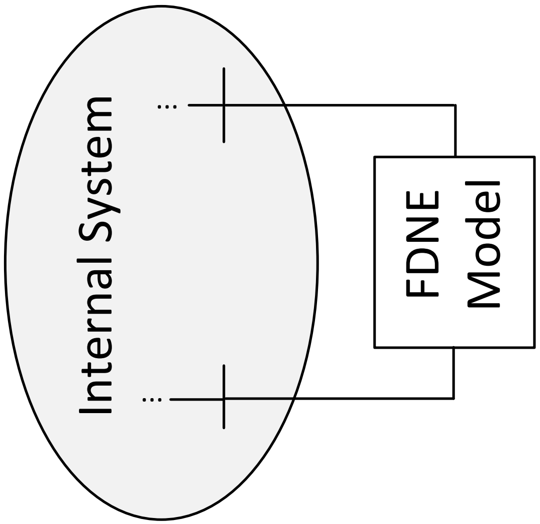
- Approach 2 – Frequency Dependent Network Equivalent (FDNE)
  - External system is modeled as a frequency-dependent mathematical model

✓ More accurate than Norton (Thevenin) equivalent

✓ Does not need buffer zone

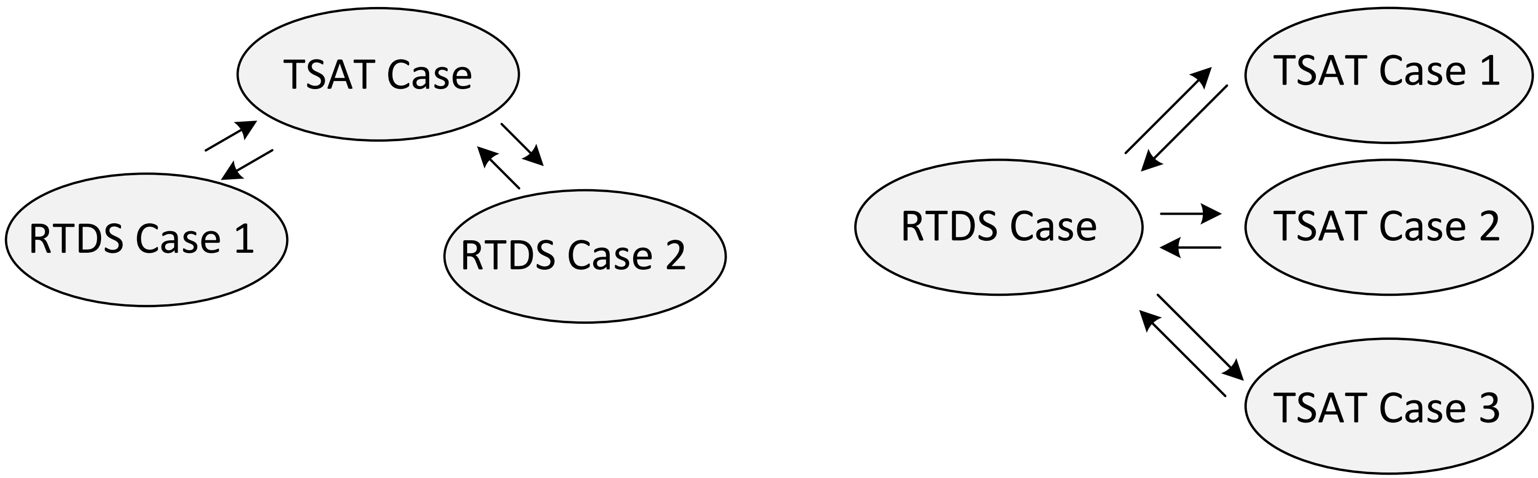
✘ Difficult to calculate

✘ Sensitive to changes in external system



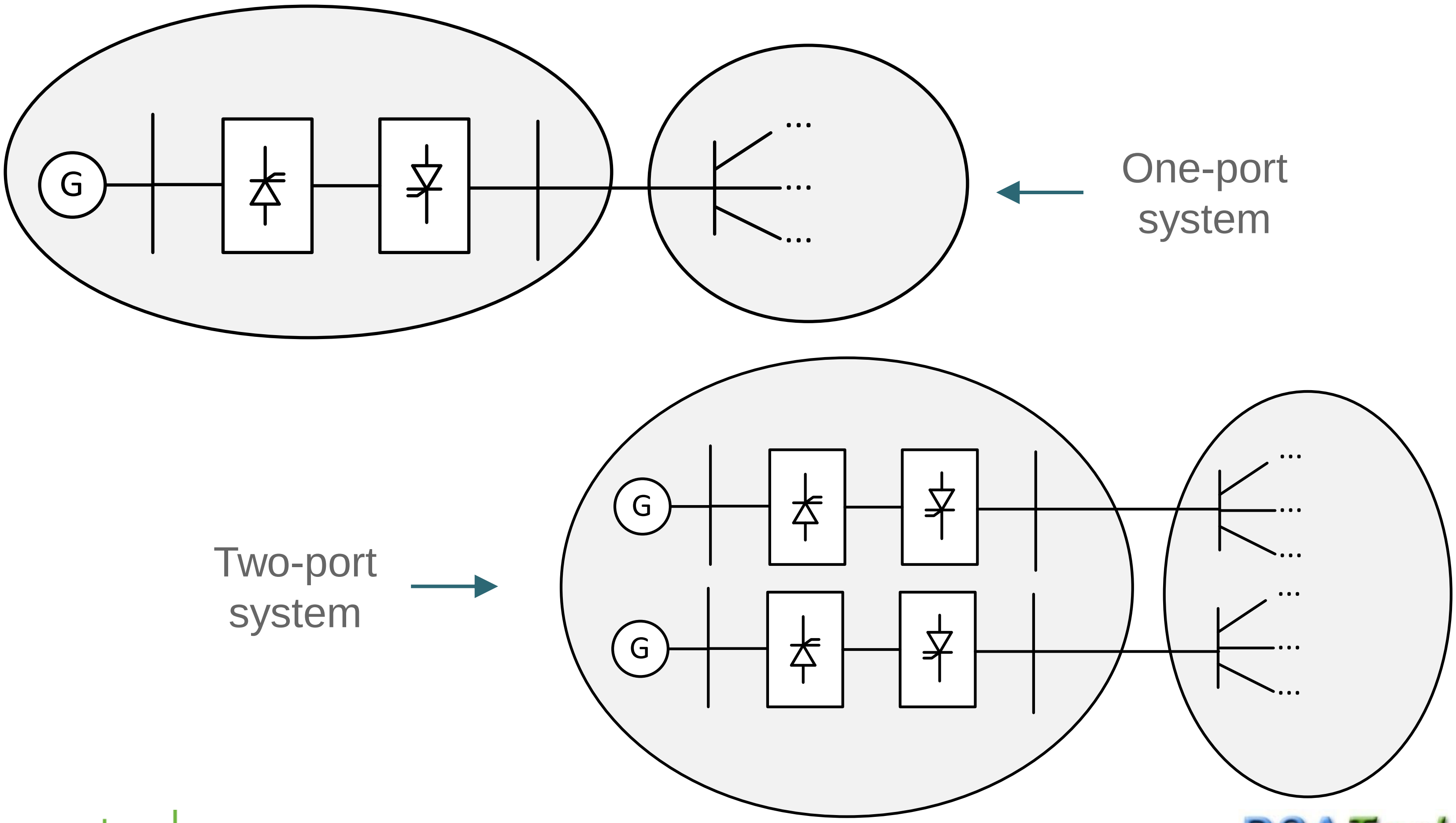
TRI Features

- Supports both Thevenin Equivalent and FDNE
- Potential TSAT-RTDS Configuration



TRI Features

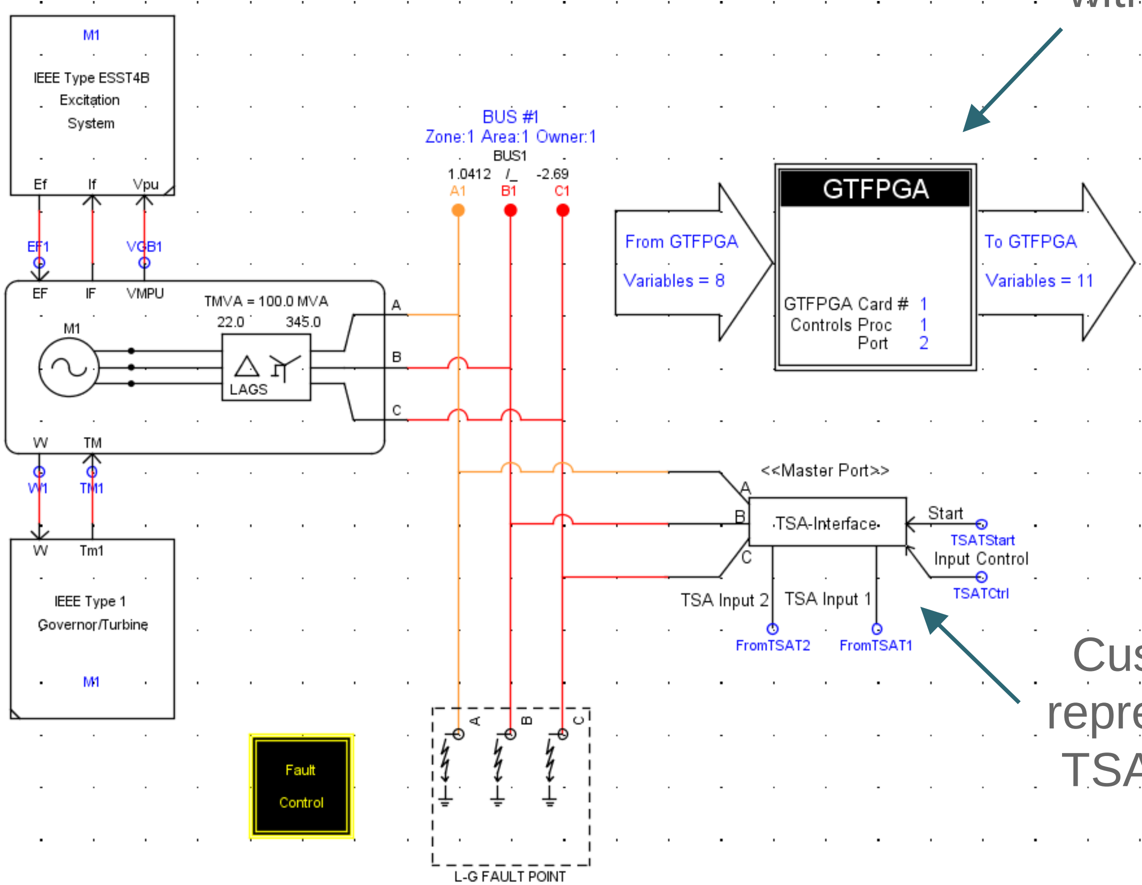
- Supports single-port and multi-port boundaries



RTDS Case Setup

- Case is being setup as normal
- GTFPGA and TSA-Interface are added

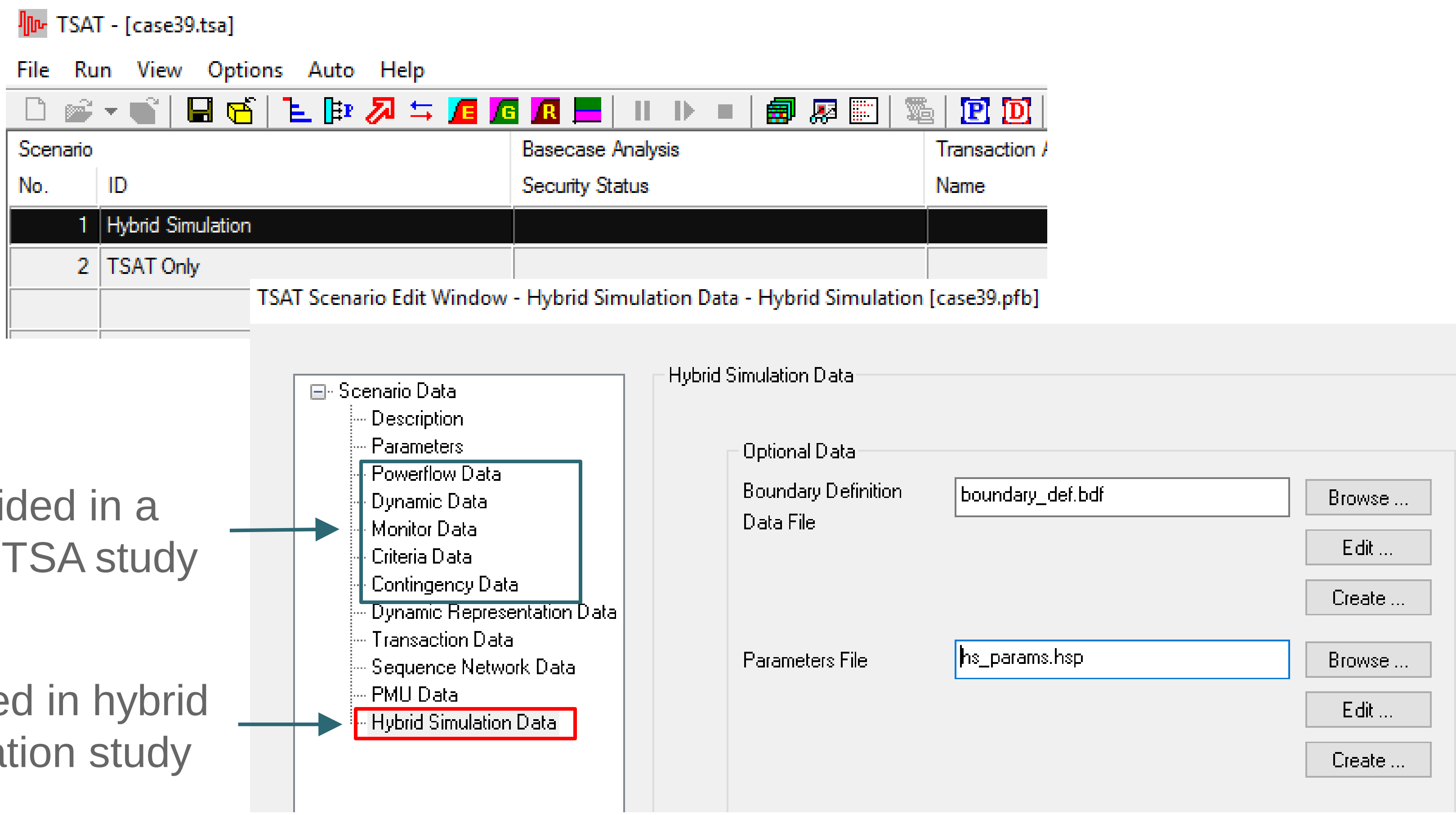
Handling data exchange with FPGA board



Custom model representing one TSAT boundary

TSAT Case Setup

- TSAT case is being setup as normal

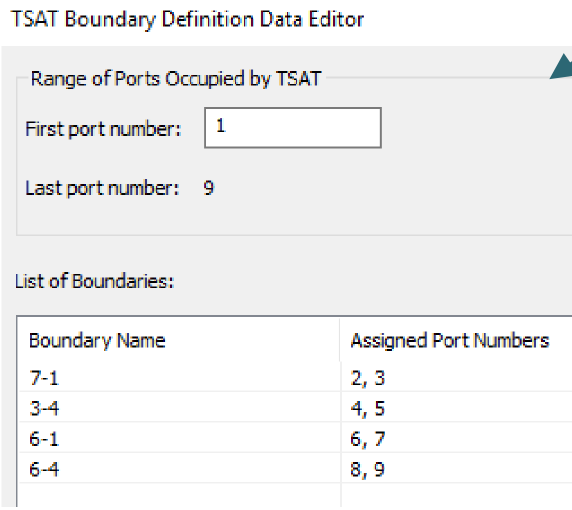


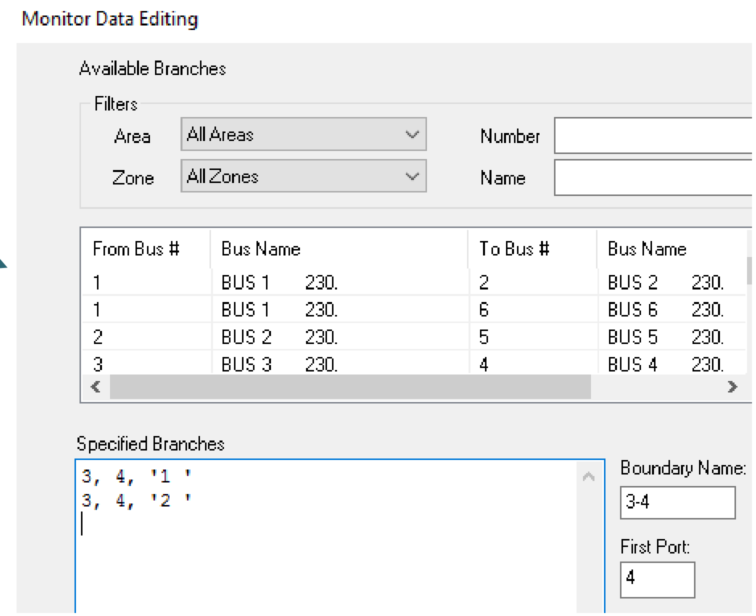
Provided in a typical TSA study

Provided in hybrid simulation study

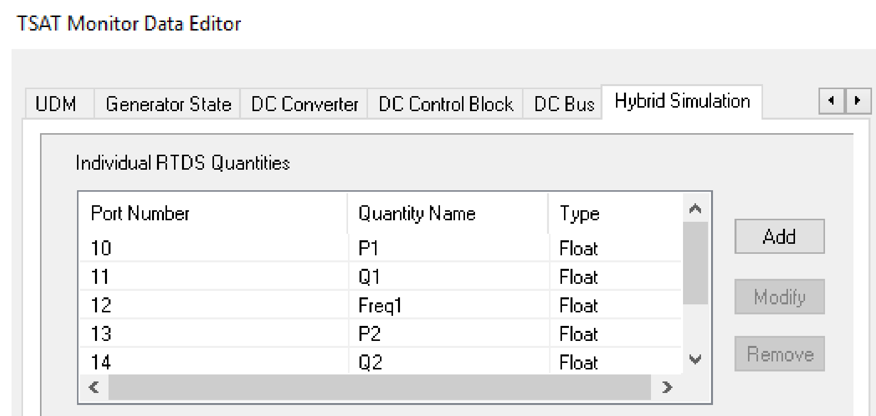
TSAT Case Setup

- Defining boundaries between internal and external systems

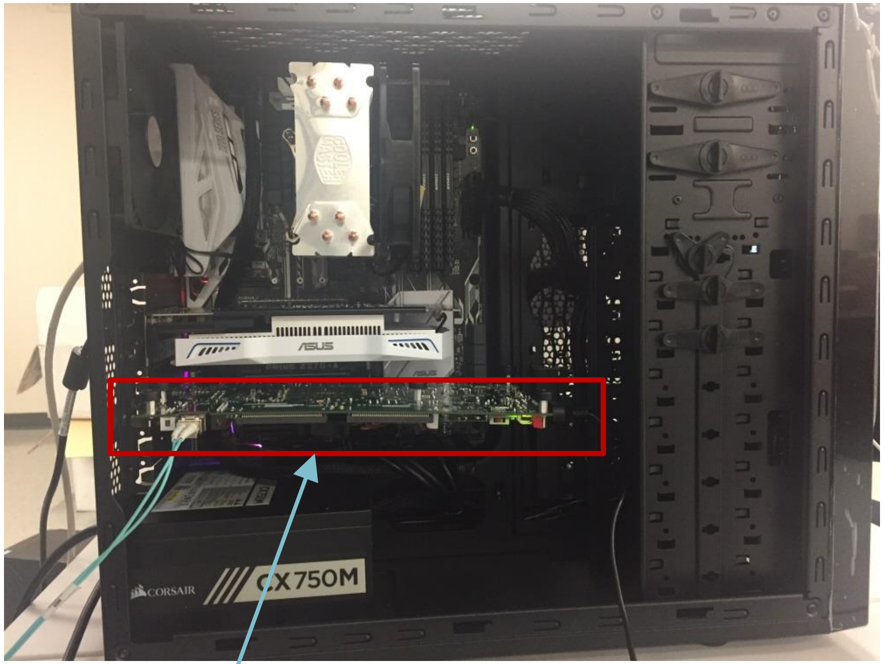


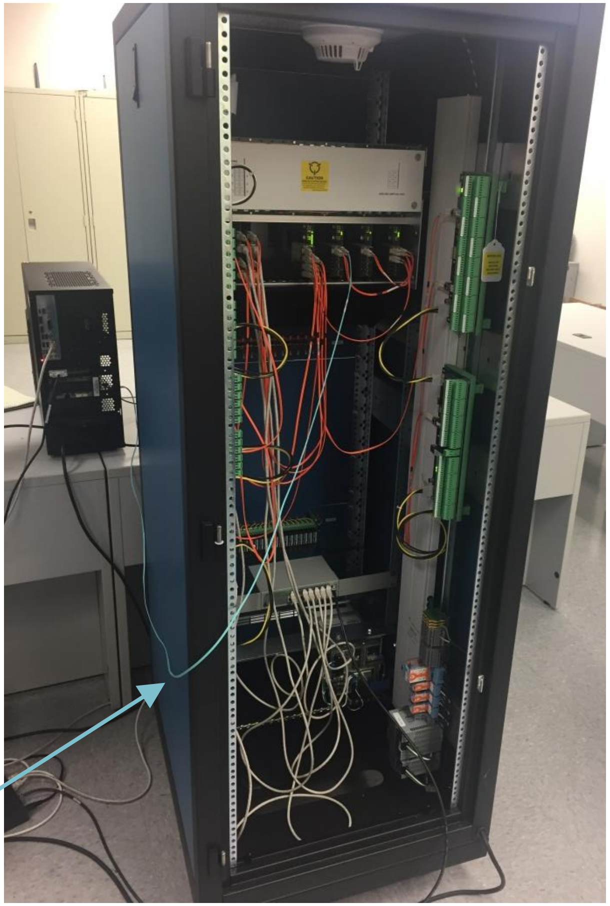


- RTDS quantities may optionally be monitored



Physical System Setup





FPGA Board mounted
on PCI Express slot

RTDS Rack connected to
PC through an optical fiber

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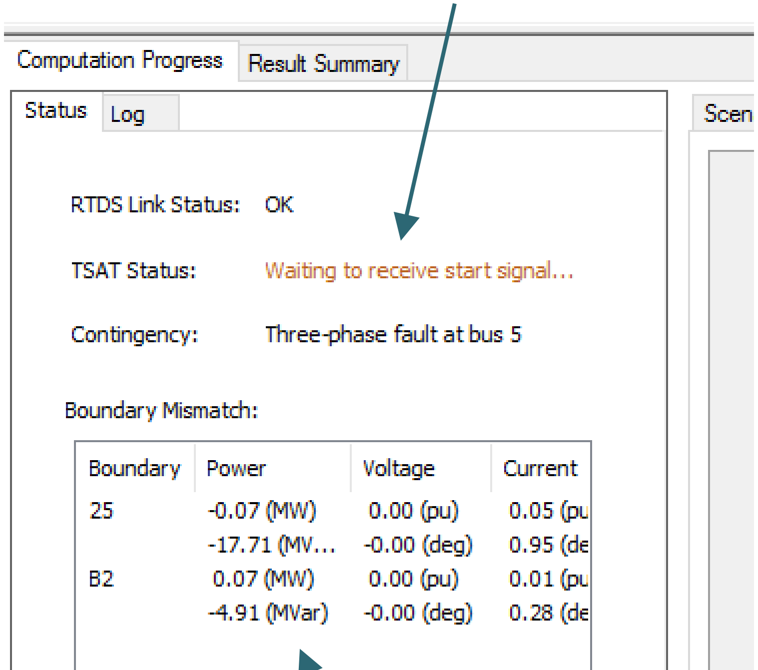
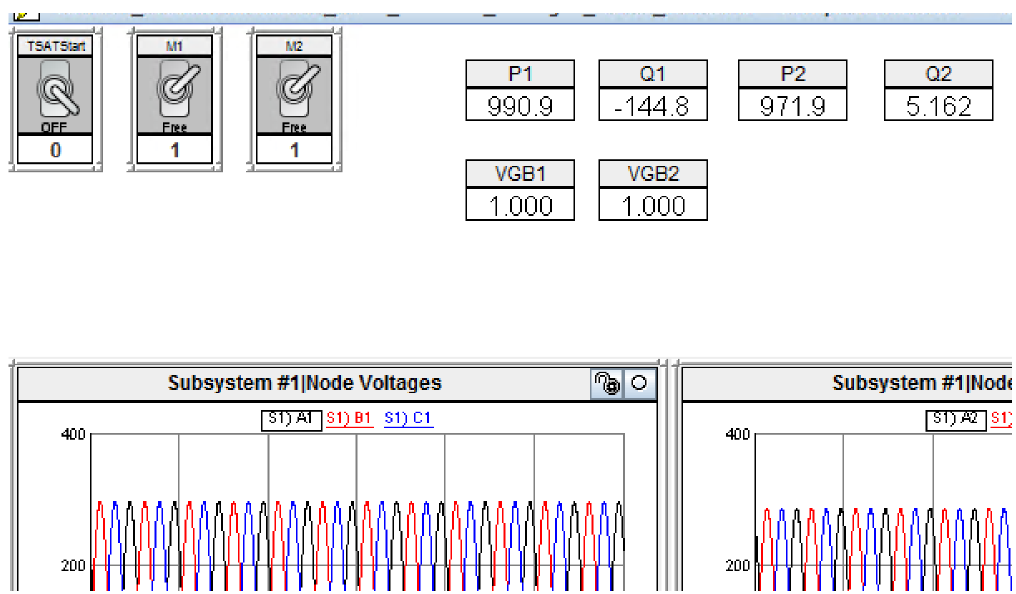
Starting Hybrid Simulation

TSAT waits during RTDS start-up

User notifies TSAT once RTDS starts-up (may automate this step in future)





Boundary mismatch can be monitored

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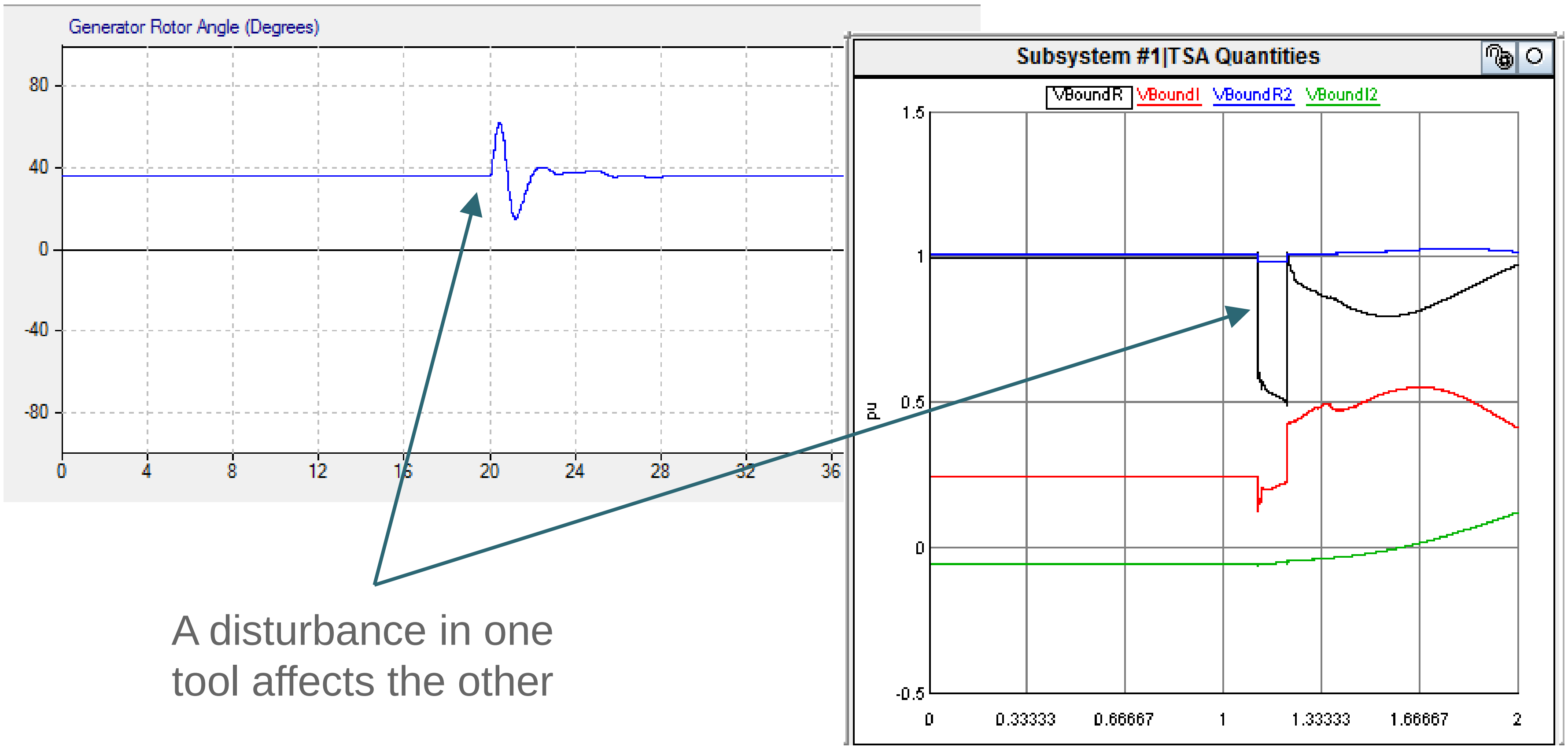
Running Hybrid Simulation

TSAT and RTDS run simultaneously

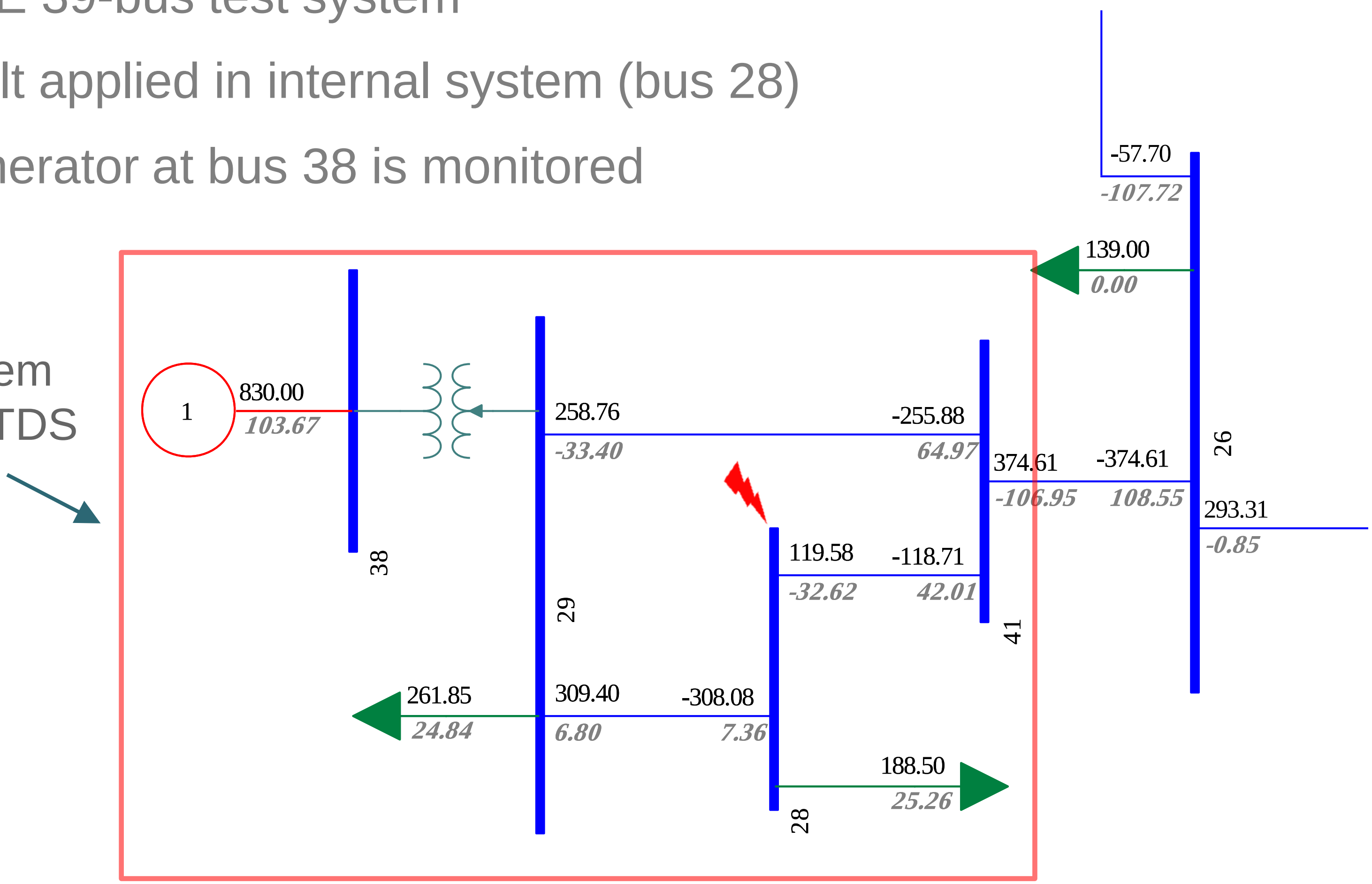


A disturbance in one tool affects the other

Case Study 1

- IEEE 39-bus test system
- Fault applied in internal system (bus 28)
- Generator at bus 38 is monitored

Internal system modeled in RTDS



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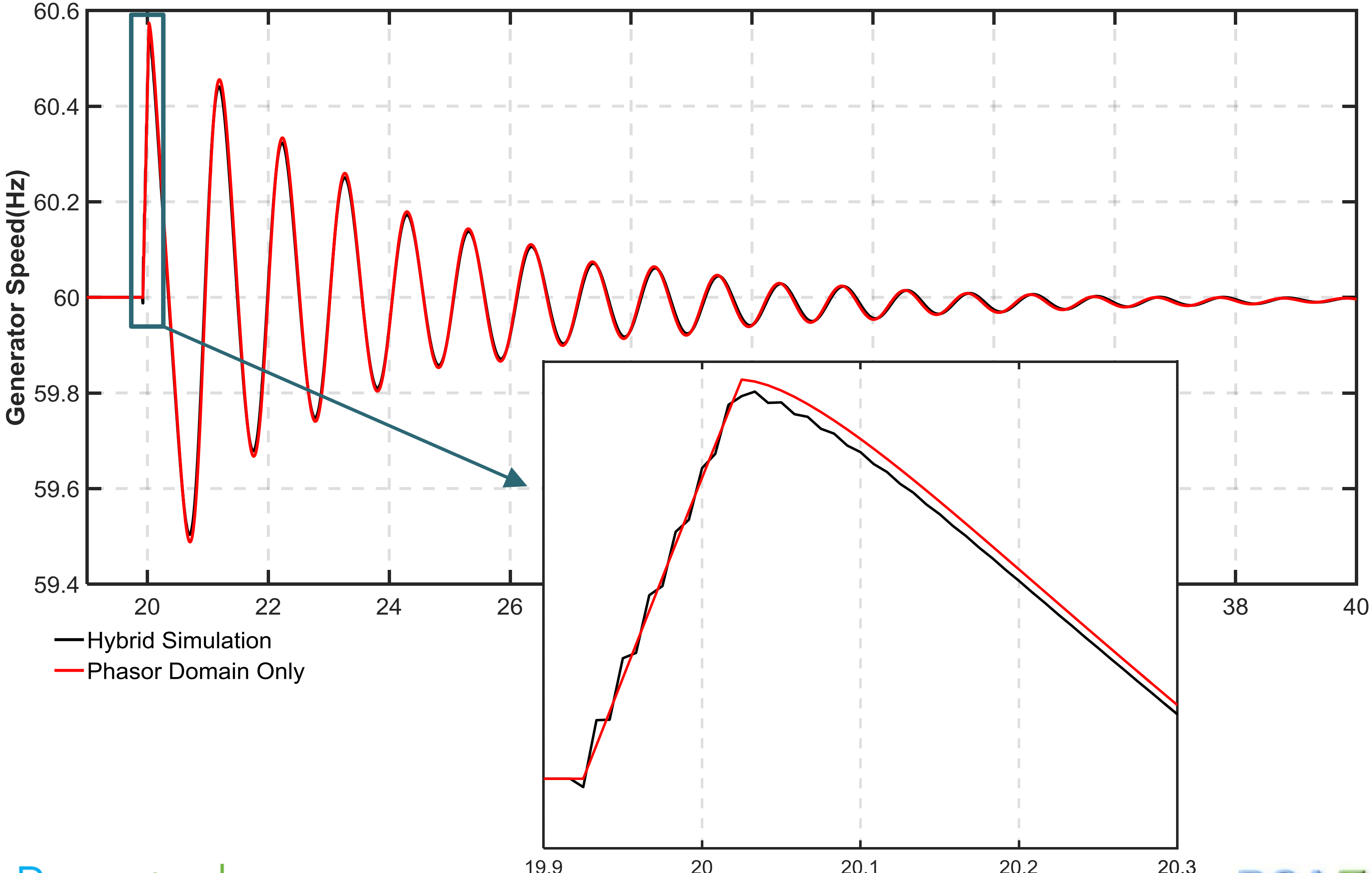
Case Study 1 – Generator Rotor Speed



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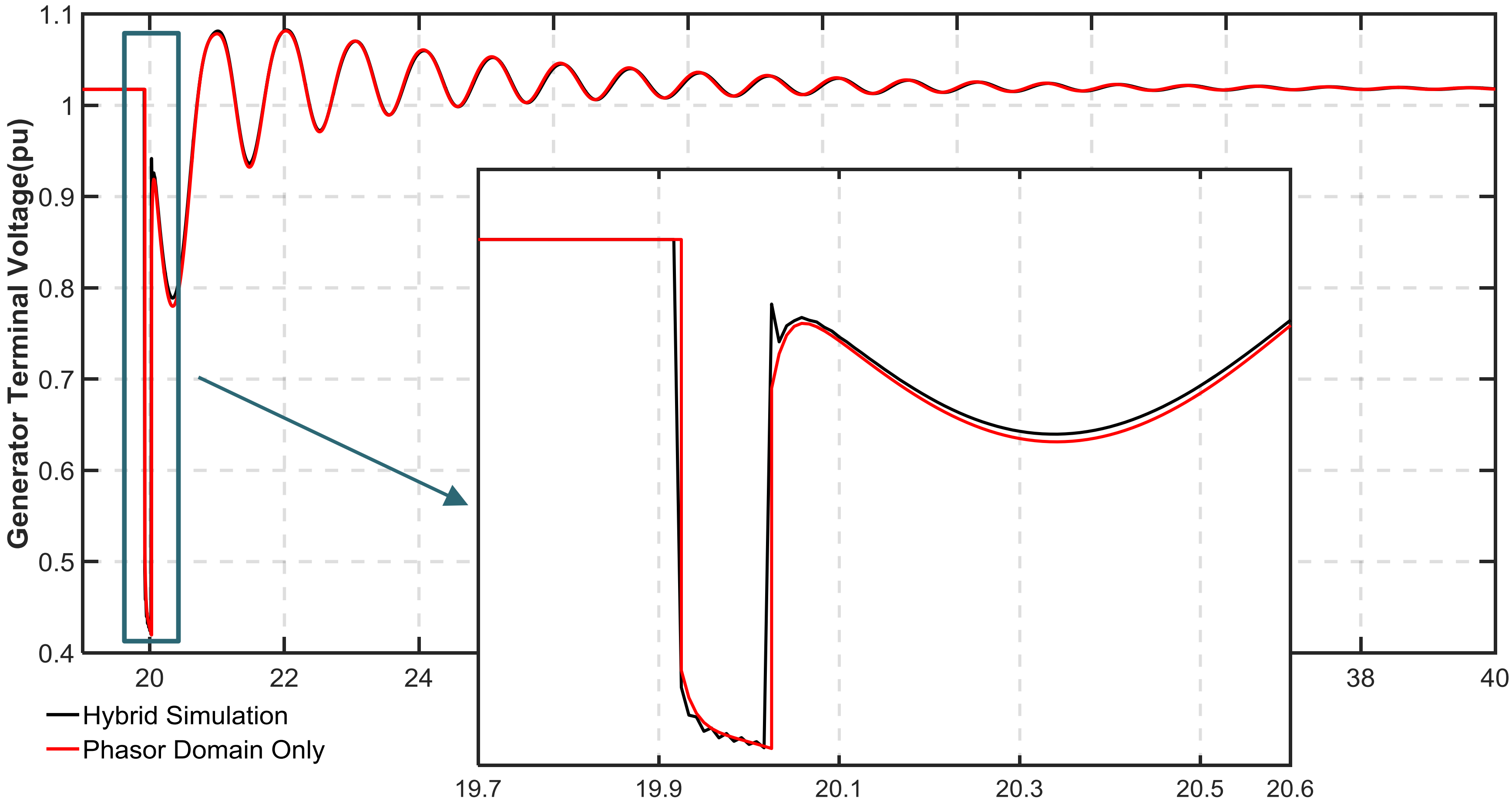
Case Study 1 – Generator Terminal Voltage



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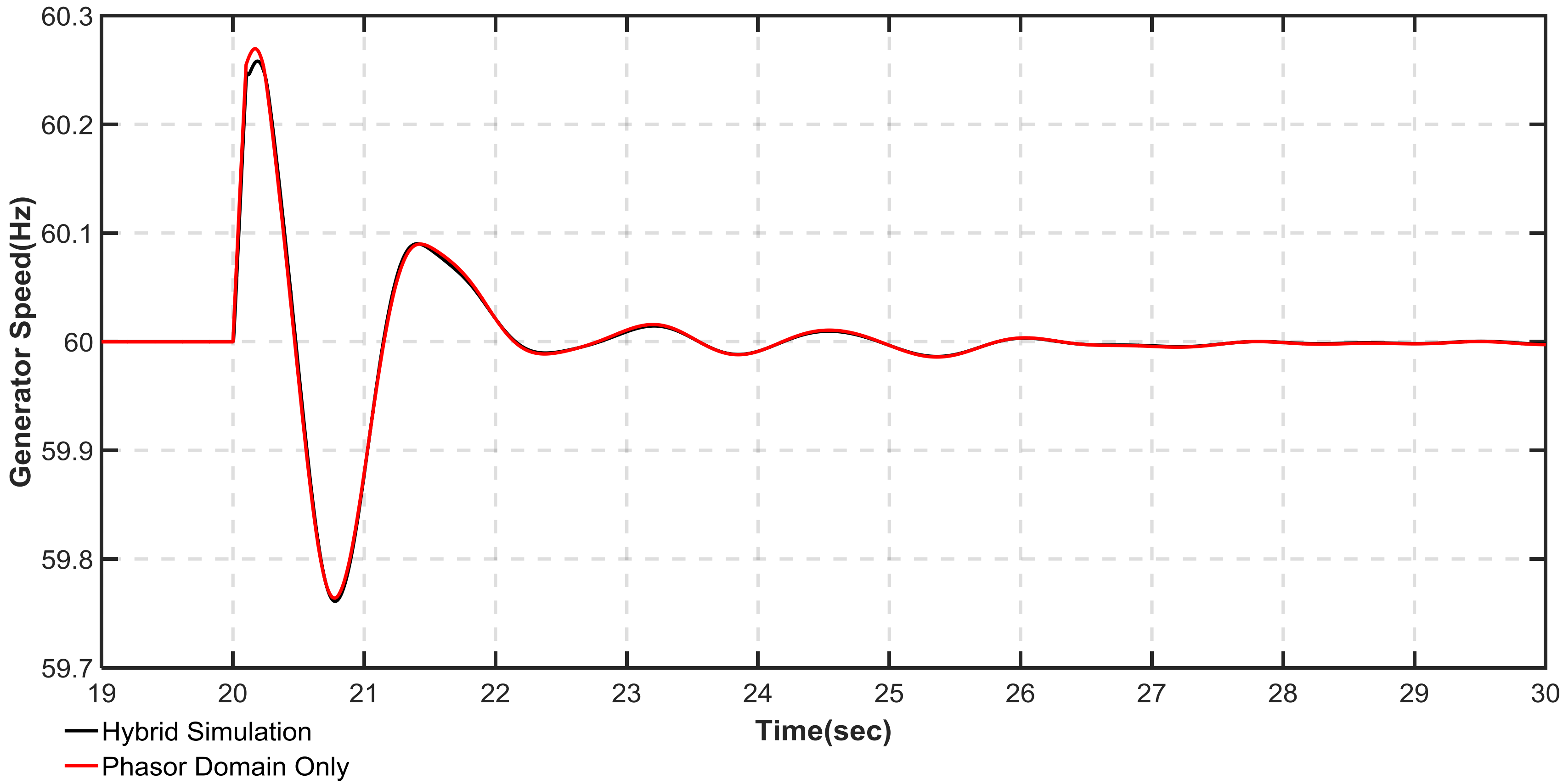
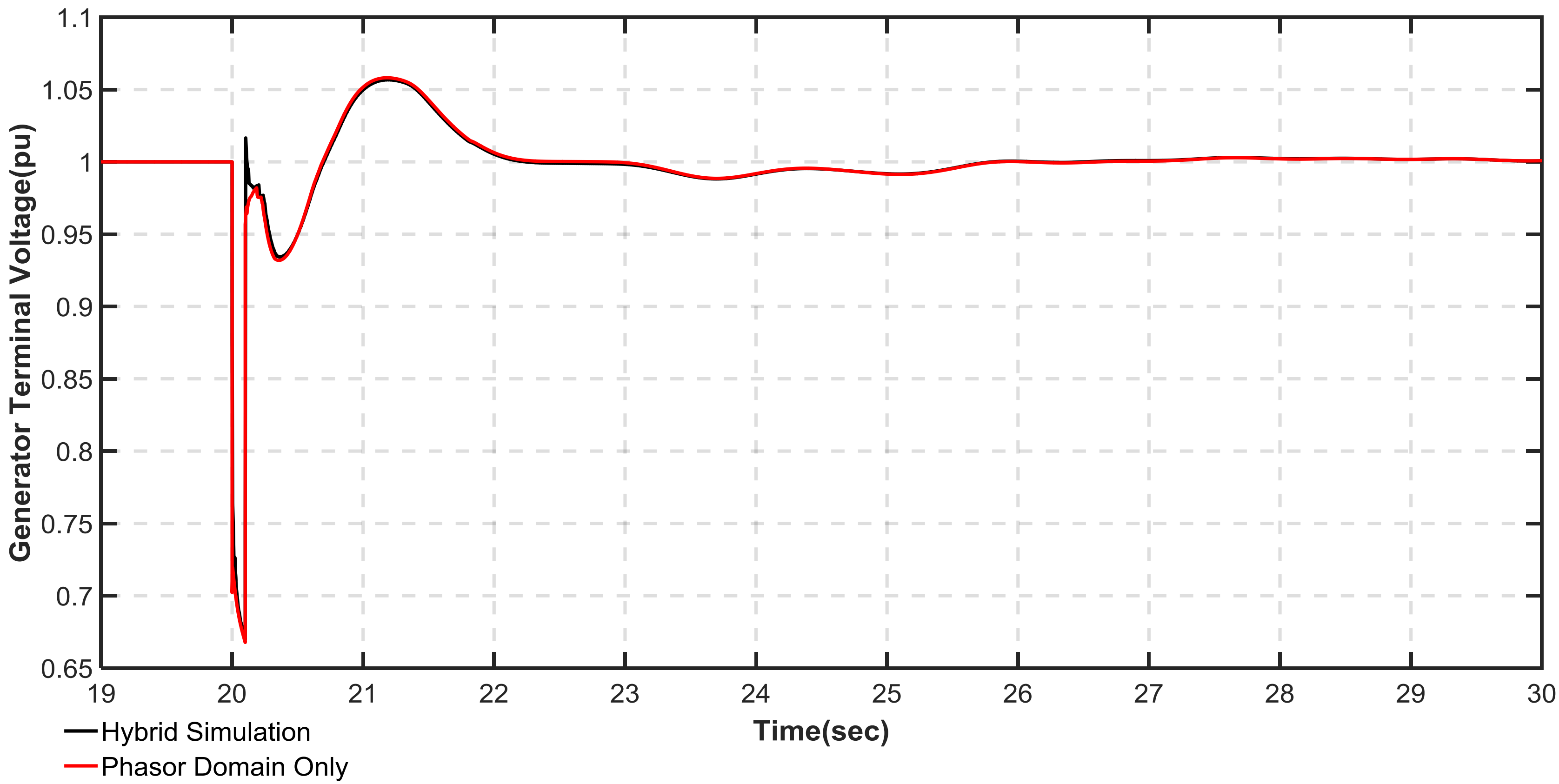
Case Study 2

- A practical case with 2189 buses and 459 generators
  - Two generators modeled in RTDS
  - Rest of system is modeled in TSAT
- Contingency description
  - Fault is applied at TSAT-side (2 buses away from one of boundaries)
  - Cleared after 0.1 seconds
- A generator close to fault is monitored

Case Study 2 – Generator Rotor Speed



Case Study 2 – Generator Terminal Voltage



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Future Plan

- Testing
  - Powertech is currently working with Yonsei University and KEPRI on testing phase
- Commercialization
  - Powertech owns full IP and commercialization right
  - The target is to release the first commercial version of the hybrid simulation interface by end of 2017
- Demonstration
  - We will demo TSAT-RTDS Interface at the IEEE PES general meeting, July 2017

Conclusion

- Why using hybrid simulation?
  - Takes advantage of both EMT and phasor-domain simulation packages
  - Facilitates analyzing interactions between low- and high-frequency transients
- TSAT-RTDS Interface
  - Performs hybrid simulation studies using TSAT and RTDS
  - Practical aspects have been one of main objectives
  - Preliminary testing demonstrated that the tool is promising
  - Allows monitoring interactions that may be missed in pure EMT or pure phasor-domain simulations