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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 highfrequency 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

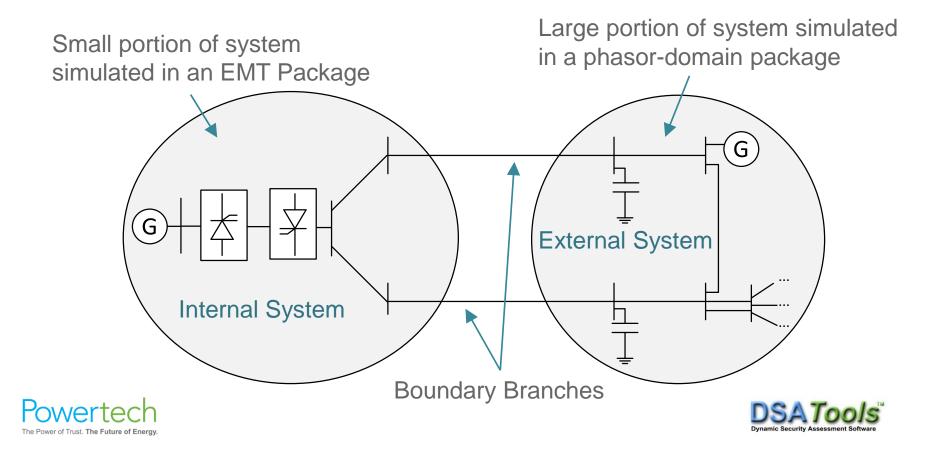
- Can focus on either detailed models in small system or simplified models in large system
 - Increasing level of details without reducing system size can be costly
- Studying interactions between system-wide events and detailed devices can be challenging, e.g.
 - Fault analysis in HVDC systems
 - Subsynchronous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







 Hybrid simulation 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







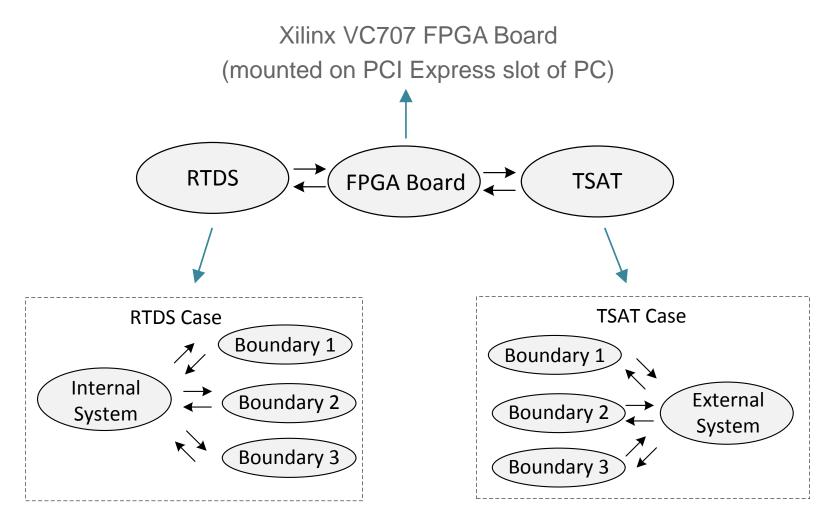
- A tool for performing hybrid simulation studies
 - Small part of system modeled in RTDS, rest of system modeled in TSAT
 - Developed by Powertech
 - With participation of Yonsei University
 - Sponsored by KEPRI
- TRI is developed with special focus on **practical aspects** to
 - Make the tool user-friendly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









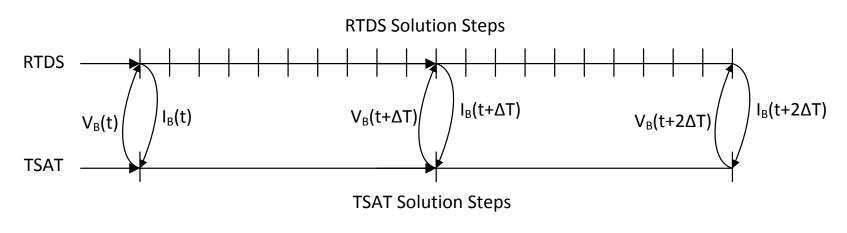








- RTDS simulates internal system at normal time-step (e.g. 50us)
- TSAT simulates external system at normal time-step (e.g. 5ms)
- Boundary injections are exchanged at the end of every TSAT integration step

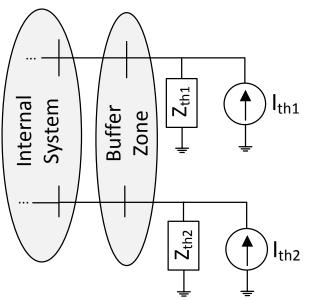






Representation of External System in EMT

- 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
 - X May fail when fault is applied at boundary
 - A buffer zone between internal and external systems is recommended

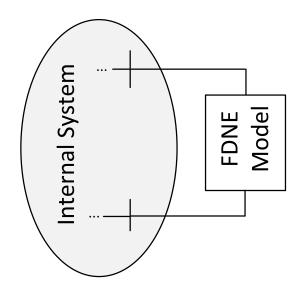






Modeling External System in Internal System

- 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

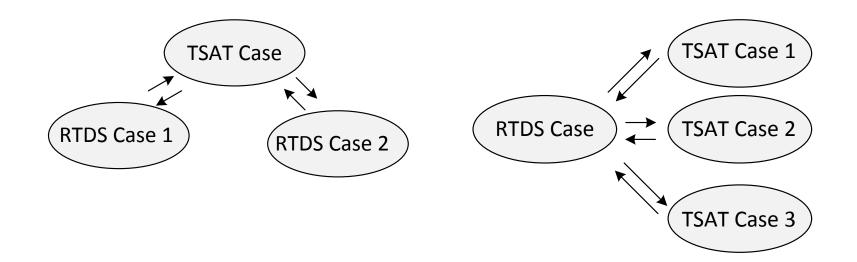








- Supports both Thevenin Equivalent and FDNE
- Potential TSAT-RTDS Configuration

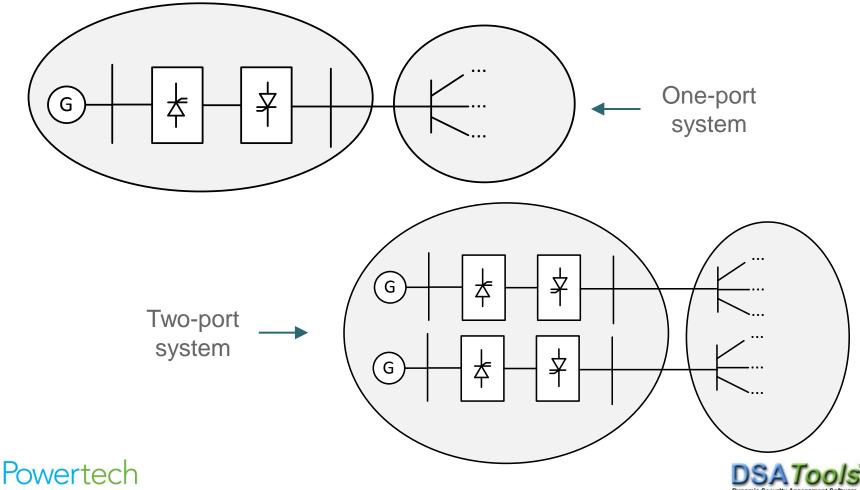








• Supports single-port and multi-port boundaries



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- Case is being setup as normal
- Handling data exchange GTFPGA and TSA-Interface are added 0 with FPGA board M1 IEEE Type ESST4B Excitation BUS #1 System Zone:1 Area:1 Owner:1 BUS1 1.0412 /_ -2.69 GTFPGA Ef lf Vpu B1 C1 A1 From GTFPGA To GTFPGA EF1 VOB1 • Variables = 11 Variables = 8 EF VMPU IF TM∨A = 100.0 M∨A GTFPGA Card # 1 22.0 345.0 Controls Proc M1 Port 2 в $\Delta \chi$ LAGS С W ΤM 杳 <<Master Port>> Φ wh Start TSA-Interface 0 TSATStart W Tm1 Input Control -0 TSATCtrl TSA Input 2 TSA Input 1 IEEE Type 1 Governor/Turbine Custom model FromTSAT2 FromTSAT1 M1 representing one ر ر ے ا ∢ . • TSAT boundary Fault Control

Dynamic Security Assessment S

L-G FAULT POINT



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• TSAT case is being setup as normal

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TSAT Case Setup

 Defining boundaries between internal and external systems

ISAT Boundary De	finition Data Edi	tor	\wedge	
Range of Ports Oc	cupied by TSAT			
First port number:	1			
Last port number:	9			
List of Boundaries:				
Boundary Name		Assigned Port Numbers		
Boundary Name 7-1		Assigned Port Numbers 2, 3		
		-		
7-1		2, 3		
7-1 3-4		2, 3 4, 5		TSAT N

RTDS quantities may optionally be monitored

Available Branches Filters All Areas Area \sim Number All Zones \sim Zone Name From Bus # Bus Name To Bus # Bus Name BUS 1 BUS 2 230. 2 230. 1 BUS 1 230. 6 BUS 6 230. 1 2 BUS 2 230. 5 BUS 5 230. 3 BUS 3 230. 4 BUS 4 230. < - 3 **Specified Branches** Boundary Name: 3, 4, '1 ' 3, 4, '2 ' 3-4 First Port: 4

TSAT Monitor Data Editor

Monitor Data Editing

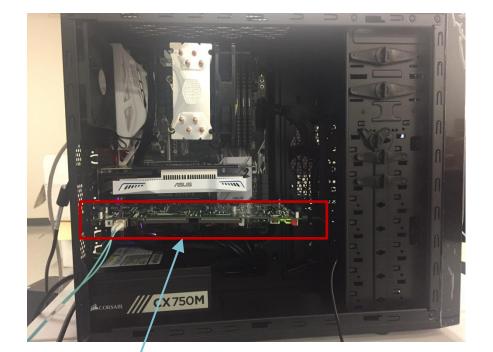
Generator State D	C Converter DC Control	Block DC Bus	Hybrid Simula	tion
ndividual RTDS Quantit	ies			
Port Number	Quantity Nam	е Туре	^	
10	P1	Float		Add
11	Q1	Float		
12	Freq1	Float		Modify
13	P2	Float		-
14	Q2	Float	¥	Remove
<			>	

Dynamic Security Assessment Software

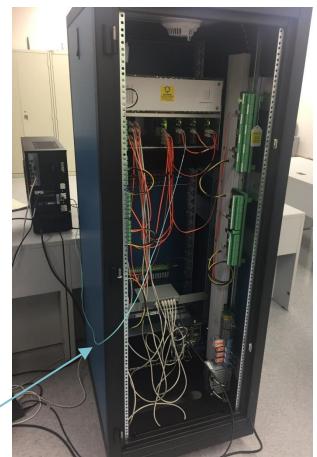




Physical System Setup



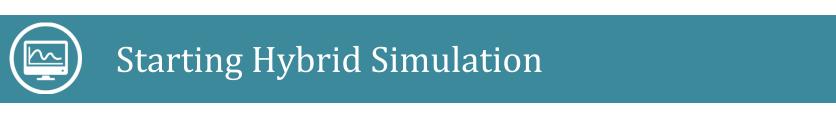
FPGA Board mounted on PCI Express slot



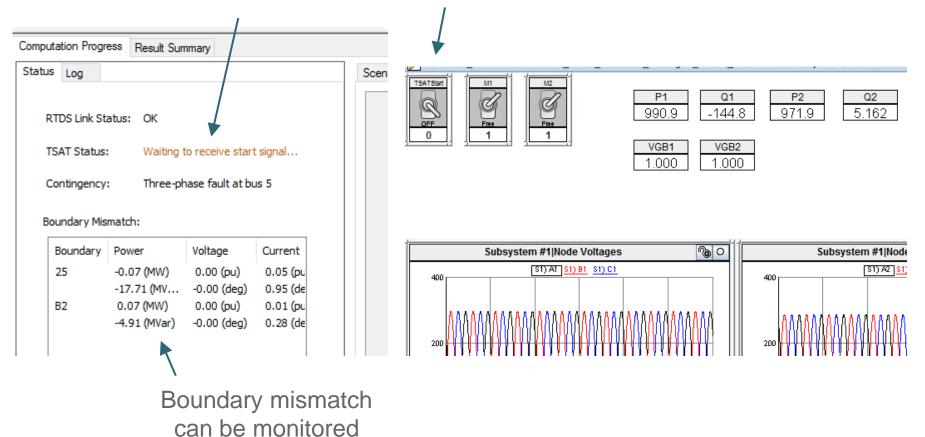
RTDS Rack connected to PC through an optical fiber







TSAT waits during RTDS start-up User notifies TSAT once RTDS startsup (may automate this step in future)

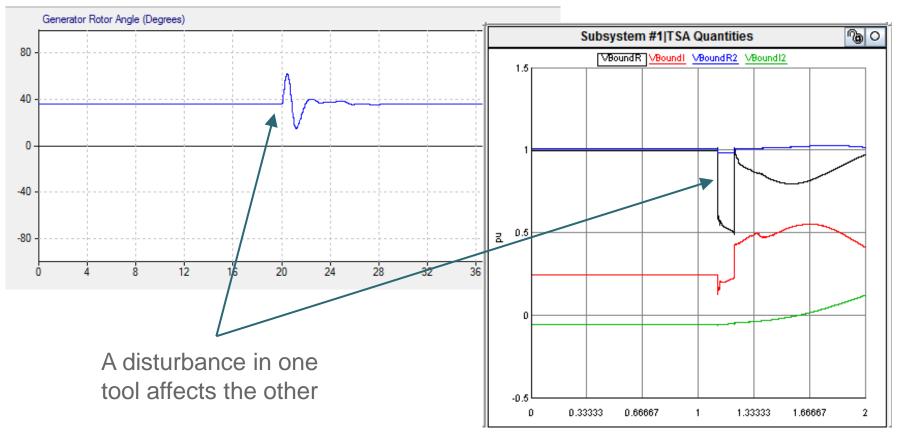








TSAT and RTDS run simultaneously





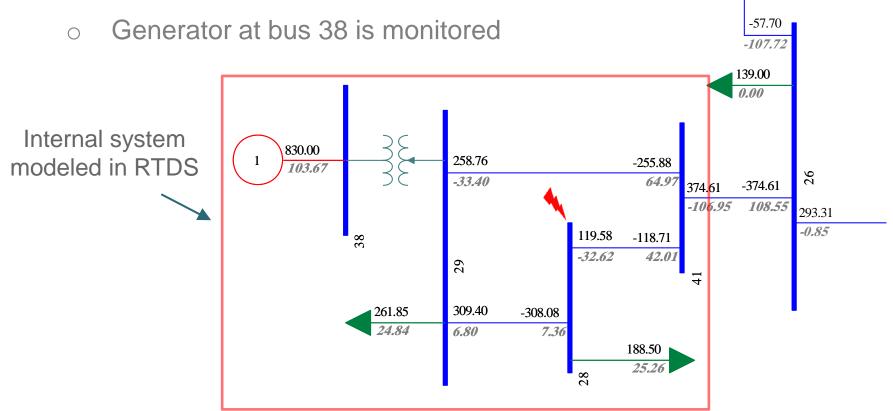




• IEEE 39-bus test system

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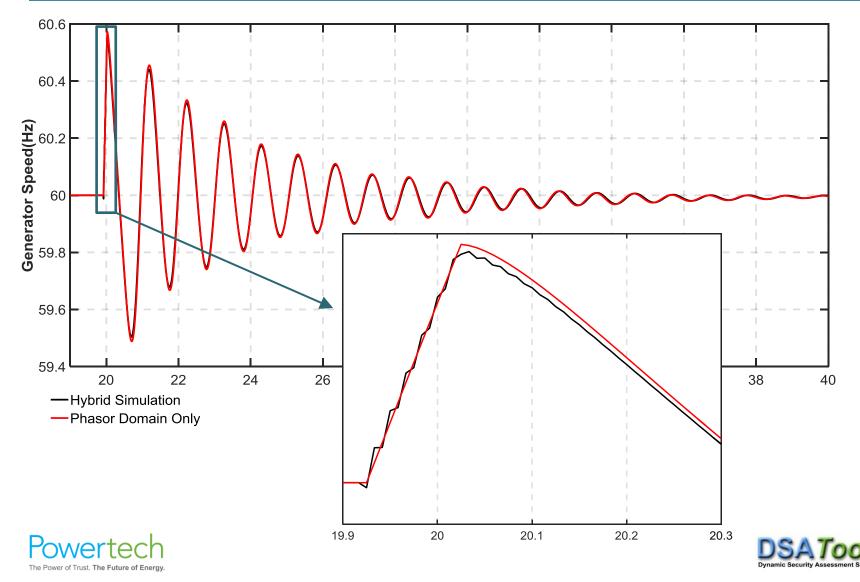
• Fault applied in internal system (bus 28)



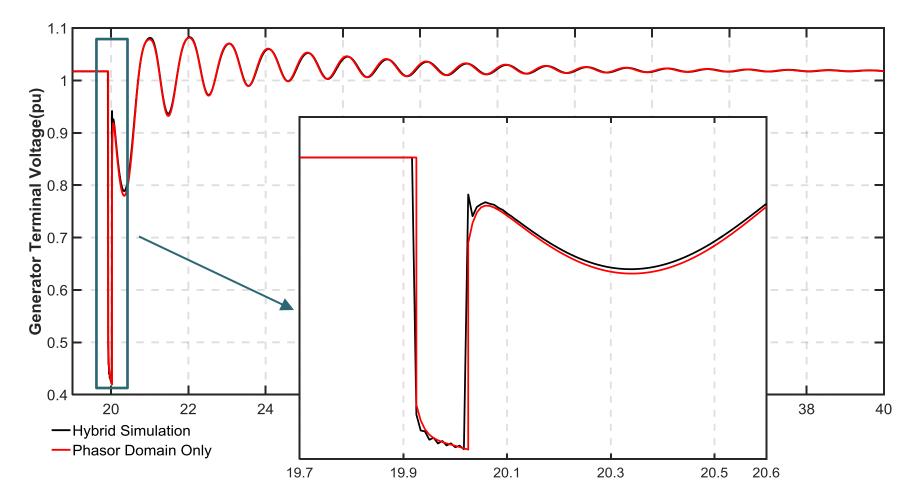




Case Study 1 – Generator Rotor Speed



Case Study 1 – Generator Terminal Voltage



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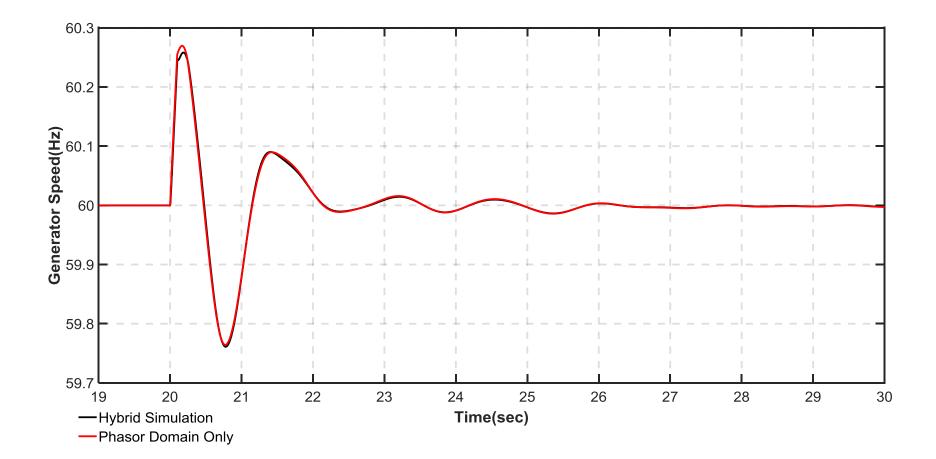
- A practical case with 2189 buses and 459 generators
 - Two generators modeled in RTDS
 - Rest of system is modeled in TSAT
- Contingency description
 - Fault is applied at TSAT-side (2 buses away from one of boundaries)
 - Cleared after 0.1 seconds
- A generator close to fault is monitored







Case Study 2 – Generator Rotor Speed

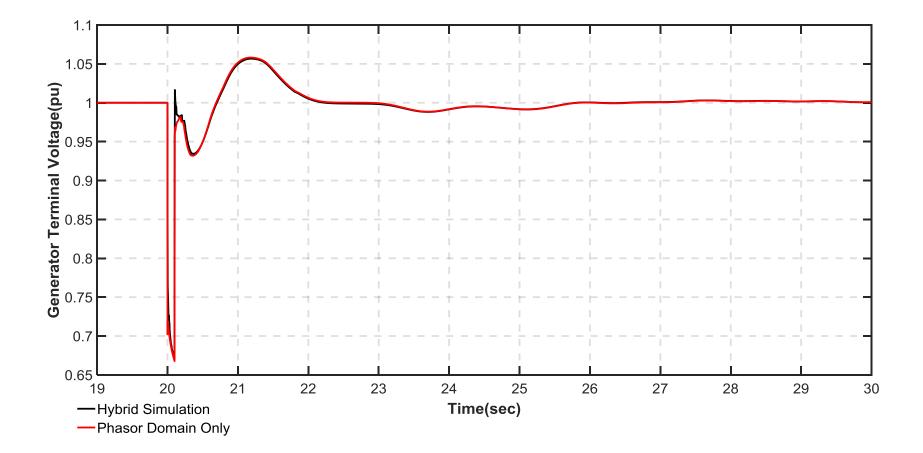








Case Study 2 – Generator Terminal Voltage









- \circ 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









- Why using hybrid simulation?
 - Takes advantage of both EMT and phasor-domain simulation packages
 - Facilitates analyzing interactions between low- and high-frequency transients
- o 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



