NEW FEATURES, COMPONENT MODELS, AND EXAMPLE CASES IN RSCAD-FX

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2023 EUROPEAN USER'S GROUP MEETING



OUTLINE

- Features, Components, and Example Cases for
 - $\circ\,$ Power Electronics Simulation
 - o Multi Energy Simulation
 - $\circ~$ Protection & Automation
 - Cyber-Physical Simulation
 - $\circ\,$ Large Scale Power System Simulation
- Other New Components
- Questions





Evolution of PE Simulation in RTDS









Universal Converter Model (UCM)

- Can run on NovaCor and PB5-based RTDS Hardware.
- Supports Different Simulation Environments.
 - SubStep (<10us)
 - o MainStep (30~50 us)
 - \circ Distribution Mode (150~200 us)
- Supports Software-in-the-loop (SIL) and Hardware-in-the-loop (HIL) Testing.
- Supports Different Inputs.
 - Modulation Waveform or Averaged Value Model
 - Firing Pulse
 - $\,\circ\,$ Improved Firing Pulse with Mean Value High Precision

Universal





UCM Components





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Renewable Energy Example Cases

- Cases include
 - Wind Energy System (Type-1, Type-3, and Type-4)
 - Solar PV System
 - \circ Power Plant Control
 - $\,\circ\,$ LVRT and HVRT Controls
- All cases use UCM model and separate versions available for
 - $\circ~\mbox{Substep}$ with switching model converter
 - \circ Mainstep with switching model converter
 - $\circ\,$ Mainstep with average model converter
- Easy to Modify (Scale/Change Ratings) and Duplicate.



Renewable Examples.pdf



Grid Forming Converters

- A Grid Following (GFL) IBR tries to hold its output current, Id and Iq, at a constant value during the transient.
- A Grid Forming (GFM) IBR tries to hold an internal voltage phasor, VIBR $\angle \theta_1$, during the transient.







Typical Grid Forming Converter Control

- Several options available to generate θ and V*

 Virtual Synchronous Generator Technique
 VF and Droop Control Technique
 Synchronverter Technique
- The voltage and current loop have limiting capabilities, and can provide fast control of the voltage at the PCC









GFM Example Cases

- Separate example cases available for each category of Grid Forming Converter Controls.
- Details about the cases are given in the help document associated with the help documents.







Grid Forming Converter Examples (Under Development)

• Wind Energy Applications



• Microgrid Applications







Electric Vehicle Example Case

- Models for Electric Vehicle and Charging Station.
- EV model uses V2G Control in Automatic and Manual modes.
- Suitable for Steady State and High-Level Control Studies.













EV Powertrain Component and Example Case (Under Development)

- Longitudinal Vehicle component has been developed.
- A detailed example case on EV Powertrain is being developed.
- Suitable for Switching Transient Studies on EV systems.







Railway Example Case

- Models/Circuits to represent
 - \circ Train Sets
 - \circ Utility Grid
 - AC Voltage Conversion
 - \circ Feeder Configuration
 - $\,\circ\,$ Trolly Lines







Impedance Scan

- Analytical Method
 - System admittance is generated using equivalent circuits.
 - $_{\odot}\,$ Suitable for conventional power systems.
- Measurement Based Method
 - o Injects voltage/currents to measure impedance.
 - $_{\odot}\,$ Can incorporate effects of operating conditions.
 - Suitable for power electronic dominated power systems









Stability Analysis Tool (Under Development)

- Configure the scan process
- View scan results

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| | | | | _ |
|--------------------------|-------------|------------------|--------------------|---|
| Stability Analysis Tool | | | | |
| a | | | | |
| equency Scan Synthesized | d Responses | Results Viewer | Stability Analysis | |
| | | | | |
| Scan Class | Measur | ement-Based | ~ | |
| Scan Type | AC Syst | em | | |
| Number of Inputs | 2 | | | |
| Start Frequency | 1 | | Hz | |
| End Frequency (Approx) | 3000 | | Hz | |
| Frequency Increment | 1 | | Hz | |
| Output File | frequence | cy_scan | | |
| | | | | |
| Impedance Output Type | Sequence | ce Impedance | ~ | |
| | | Balanced 3 Phase | e Network | |
| Perturbation Parameters | | | | |
| | | | _ | |
| Perturbation Size | | 3 | % | |
| Injection Base(s) | | 230, 115 | | |
| # Frequencies per sub | range | 50 | | |
| # of sub-ranges | | 60 | | |
| System Settling Time | | 10 | S | |
| DFT Calculation | | | | |
| | | | | |
| Sampling Window S | ize | 1 | ∨ s | |
| # of Samples | | 10000 | | |
| | | | | |
| | | | | |
| | | Start Scan | Cancel | |
| | | | | |







Stability Analysis Tool (Under Development)

- Synthesized Response
- Stability Analysis

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| | Frequency Scan Synthesized Responses Results Viewer Stability Analysis |
|--|---|
| 🖳 Stability Analysis Tool | $\begin{array}{c} \text{scanO15cn} \\ \text{scanO25cn} \\ \text{scanO35cn} \\ \text{scanO4 fscn} \end{array}$ |
| Frequency Scan Synthesized Responses Results Viewer Stability Analysis Start Frequency 0.1 Hz End Frequency 3000 Hz Output File frequency_scan Type Series RL Impedance Output Type Sequence Impedance | System 1 scan01 facm System 2 scan02 facm Stat Frequency 0 1 End Frequency 3000 Impedance Output Type Sequence Impedance K 10 tau 0.0 us Sequence Area and the sequence Hz tau 0.0 us Stat Frequency 50 Hz tau 0.0 us Sequence Area and the sequence Sequence Area and the sequen |
| M_{R} L_{L} L M_{R} L L M_{R} L $\omega_{0}L$ L $\omega_{0}L$ L Resistance 2.4 OhmsInductance 0.075 H | Measured 0.3 kHz 1 Hz Skep Size AC inpedance (PN0) 230 KV base votage 25% perturbation 2 x 2 matrix Tdd (ab.c.d.ef) Tdq (ab.c.d.ef) Tqq (ab.c.d.ef) |

🖳 Stability Analysis Tool





- 🗆 🗙

MMC Model for Mainstep (Under Development)

- An improved model of MMC to run on mainstep
- This eliminates the need of transmission line interface between the substep to mainstep.





MULTI ENERGY SIMULATION

Hydrogen System Models and Example Cases



| Example Cases | |
|---|---|
| Name | |
| 05 Energy Storage Systems | |
| Battery Systems | |
| FlyWheel and Pumped Storage Systems | |
| Fuel Cells | |
| ▼ MEF | |
| MEF_ELZ_H2production | |
| 🗋 ELZplant.jpeg | |
| 🔀 MEF - Hydrogen Production via Electrolysis.pd | f |
| MEF_ELZ_H2production.rtfx | |
| MEF_FCplant2grid | |
| 🗋 H2powerplant.jpg | |
| 🔀 MEF - Fuel Cell Power Generation.pdf | |
| HEF_FCplant2grid.rtfx | |







MULTI ENERGY SIMULATION

Hydrogen System Connection









MULTI ENERGY SIMULATION

Alkaline Electrolysis Model and Example Case (Under Development)



Alkaline Electrolyzer stack



Grid connected AWEL plant via a six-pulse thyristor rectifier





GSE-v7 Component

- Provides IEC 61850-8-1 Ed. 2.0 / 2.1 GOOSE communication and MMS Server functionality
- Simulates up to 4 IEDs (Generic or Third Party)
- Publish up to 16 GOOSE messages (4 GCBs per IED and 512 data items in total)
- GOOSE subscription up to 32 different GOOSE streams (512 data items in total)







IED Configuration Tool (ICT)

- Build IEC 61850 data models from the inbuilt LN database
- Emulate third-party IEDs from SCL files
- Bind input/outputs to RSCAD FX draft signals
- Import non-RTDS SCL files for GOOSE subscription configuration
- Generate CID and other auxiliary configuration files for GSE components







SimIED Feature

- Emulate third-party IEDs
- Supports any valid IEC 61850 SCL file (such as ICD, CID or SCD) with one or more IEDs
- Only standard data types and LN classes are supported (as defined in IEC 61850-7-x)







Sub Synchronous Oscillation (SSO) Relay Model

- Supports 'Single' and 'Multiple' frequency modes (up to 3 SSO elements)
- Monitor SSO frequencies and corresponding magnitudes

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New Set of Protection and Automation Example Cases

- Protection Examples
 - \circ Generator Protection
 - Series-compensated Line Protection
 - SSO Protection
- Automation Tutorials/Examples
 - GTNET Tutorials comprises a set of new tutorial cases that systematically present the process of simulating GTNET protocols
 - MODBUS Example Case





Editors for SCADA Protocols

- Automatic conversion of legacy text-based mapping file to XML-based file.
- Description fields for each point to better identify the purpose of the simulation.
- Intuitive combo-box options in each point's cell data.

| 104 IEC (| 🚾 IEC 60870-5-104 Editor, version:1.00-b29 2022-12-01 12:25:23 — 🗆 🗙 | | | | | | | × | | | | |
|-----------|--|--------------------|---|------------------|--------|--------|-----------------|--------------------|-------------|------|---------|---|
| File | Edit | Help | Set Type Type: 2.0 maximum 10 outstations. Close database to change type! | | | | | | | | | |
| Outstat | ion Bina | ry Status Dpos Sta | tus Analog S | Status Binary Co | ontrol | Dpos C | ontrol Analog (| Control | | | | |
| IOA | IOA_M | Variable Name | Bitmap | Default State | Group | Mask | Select Required | | Description | | | |
| 10000 | 9512 | BRK_ctl_104 | 0 - | 1=OFF 🔻 | 0x9 | | false 🔹 | Breaker Open/Close | e Operation | | | |
| | | | | 0=intermediat | e | | | | | | | |
| | | | | 1=OFF | | | | | | | | |
| | | | | 2=ON | | | | | | | | |
| | | | | 3=indetermina | ate | | | | | | | |
| | | | | | | | | | | | | |
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| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
| #Points | 1 | - | | | | | | | | | | |
| Outst | ation_1 | - (| 30 | New | |] Cor | py | ete 💽 Save | RTDS | Data | a Set 1 | • |
| | | | | | | | | | | | | |
| | | | | | | | | | | | | |
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GTNETx2 Merging Unit with PRP Support (Under Development)

- Provide the GOOSE, SV and MMS functionality necessary to emulate MUs
- Support Parallel Redundancy Protocol (PRP) for GOOSE and Sampled Values networks
- Since both LAN A and LAN B ports are required for the redundancy the GTNETx2 card will only run one firmware version when the redundancy feature is enabled









Traveling Wave Relay Model (TWR) – Based on Differentiator-Smoother (DS) Technique (Under Development)

- Includes current TW different protection scheme (TW87):
- Uses double-ended TW-based method.
- Supports single/three-pole tripping.
- Provides calculated fault location and faulted mode information.
- Option to detect an external fault on a parallel line.







Incident Wave Calculator (IWC) Model (Under Development)

- Uses Frequency Dependent Phase Domain (Universal Line Model) transmission line theory to calculate:
 - \circ The local incident current.
 - $_{\odot}\,$ The local reflected current.
 - \circ The expected remote incident current.









RTDS Simulator Interfaced with NS3 Network Simulator

- Advantages:
 - Can model an entire communications network.
 - Can Modify packets and frames of Protocols DNP3, MODBUS, IEC104, PMU, GOOSE and SV.
- Limitations:
 - The amount of traffic it can handle is limited.



Linux PC running NS-3 using the Tap mode

UGrid controller





Example Cases to Run Jointly with NS3

- Separate examples are provided to alter data for
 - o DNP3,
 - \circ MODBUS
 - o IEC104
 - \circ PMU
 - $\circ~$ GOOSE and SV

| Name | |
|---|--|
| 09 Machines and Drives | |
| 10 Transformers | |
| 🛅 11 Cybersecurity | |
| GTNET and NS3 | |
| ▼ T GTNET_GSE | |
| GOOSE_Communication.idf | |
| GOOSE_Communication.pdf | |
| GOOSE_Communication.rtfx | |
| GSE_TRIP.iaf | |
| GSE_TRIP.ipf | |
| 🕒 GTNET1.cid | |
| 🕒 GTNET2.cid | |
| PeakShaveTCP_rtfx | |
| ControlScriptTCP.scr | |
| CyberSecSimPeakShaveTCP.rtfx | |
| PeakShaveUDP_rtfx | |
| ControlScriptUDP.scr | |
| CyberSecSimPeakShaveUDP.rtfx | |
| GTNET and NS-3 for CyberSecurity Simulation.pdf | |





RTDS Simulator Interfaced with SNORT Packet Modifier









Example Cases to Run Jointly with SNORT

- A Linux machine running the packet modifier is placed between the actual Client (User PC running P&A suite) and the Server (GTNET card) for the TCP/IP based protocols
- We cad add delay, jitter, reorder, corrupt, duplicate or drop packets.

| Name | | | | | |
|---|--|--|--|--|--|
| 10 Transformers | | | | | |
| 11 Cybersecurity | | | | | |
| GTNET and NS3 | | | | | |
| ▼ CTNET_DNP | | | | | |
| GTNET_ DNP.pdf | | | | | |
| GTNET_DNP.dfx | | | | | |
| GTNET_DNP.dtp | | | | | |
| GTNET_DNP.sib | | | | | |
| pointsMap.txt | | | | | |
| ▼ 🛅 GT_GT_FX | | | | | |
| GTENT_IED2.scd | | | | | |
| GTENT_IED2converted.CID | | | | | |
| GTNET_IED1.scd | | | | | |
| GTNET_IED1converted.CID | | | | | |
| 🕒 GT_GT.iaf | | | | | |
| 🕒 GT_GT.idf | | | | | |
| 🕒 GT_GT.ipf | | | | | |
| 🖶 GT_GT.rtfx | | | | | |
| GT_GT.sib | | | | | |
| GT_GTGSEcomponents.dpf | | | | | |
| T_GT_GT_original_2023-09-15@15_12_928.zip | | | | | |
| Standalone packet modifier for ICS.pdf | | | | | |
| 12 Traction Systems | | | | | |

Example Cases









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Superstep Simulation



Conventional Single-Rate Simulation (218 nodes and 2980 load units on Chassis)



Saving of ~ 500 Loadunits





Transient Stability Analysis (TSA) Module

- TSA module in RTDS intended to:
 - Represent a portion of a larger power system (up to ~2000 buses) using an equivalent TSA component.
 - Interface TSA module with EMT simulation (co-simulation/ hybrid simulation)
 - o Standalone TSA simulation is also supported.
 - Reduced number of cores (TSA module requires one core).

| TSA | |
|-----|--|
| | |







EMT-TSA Interface









PSCAD-RTDS Co-Simulation

- Interface between NovaCor simulator and PSCAD has been developed.
- Main application is to run Blackbox models running in PSCAD which cannot be successfully migrated to RTDS.
- Intended for non-real time applications.

IIRTDS

• Control interface has been released and electrical interface is under development.



Electrical Interface





PSCAD-RTDS Co-Simulation

- UDP communication.
- PSCAD V5 Support only.







Data Conversion Programs

• RSCAD supports conversion of cases from other widely used offline tools









PowerFactory (PF) Conversion Program

- Similar to the PSCAD Conversion.
- Conversion can be customized.

| Options | | | × |
|---------------------------------|---|-------------------------------|---|
| General Options Case Options | 4 | Initial Directory: | C:\RTDS_USER\fileman\Projects\DIgSILENT\Testing |
| Monitoring Options | | Starting Rack: | 1 |
| | | Timestep (µs): | 50.000 |
| | | Nodes / Network: | 300 |
| | | Networks / Rack: | 1 |
| | ¥ | Autoroute Limit (Grid Units): | 50 |
| | | Save as Defaults | Close |





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PowerFactory (PF) Conversion Program Example







Enhanced Non-Real Time Simulation (Under Development)

- To help
 - $\circ\,$ EMT network planning studies
 - \circ Consultants
- Support larger network (~10 times the capacity of NovaCor 1.0)
- Larger execution timestep (> 200 µs)
- No support for I/O and GTNET
- Will Support GTSOC





OTHER NEW COMPONENTS

Recently Released RSCAD Components

- Faulted Induction Machine
- Super Capacitor Bank

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- Dual Active Bridge (DAB) UCM with scaling
- UMEC transformer models with hysteresis



VALVE 2

VALVE 4

VALVE 4





Questions?



