WEBINAR

ELECTRIC MACHINE MODELS FOR THE RTDS SIMULATOR

APPLICATION: GENERATOR PROTECTION AND CONTROL TESTING

RTDS Technologies

RTDS.COM

RTDS TECHNOLOGIES - THE COMPANY

- Based in Winnipeg, Canada
- ~75 employees
- World pioneer of real-time simulation and exclusive supplier of the RTDS Simulator
- Representatives in over 50 countries
- Hardware and software development, model development, customer support, sales and marketing, finance, product assembly and testing all under one roof

WORLDWIDE USER BASE

Manufacturers

WORLDWIDE USER BASE

Utilities

WORLDWIDE USER BASE

Research and educational institutions

NREL
NATIONAL RENEWABLE ENERGY LABORATORY

University of Strathclyde

MANCHESTER 1824
The University of Manchester

DTU Technical University of Denmark

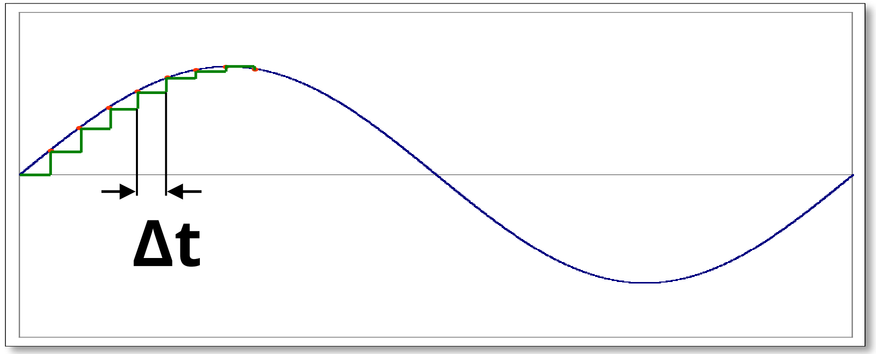
DUT DURBAN UNIVERSITY OF TECHNOLOGY

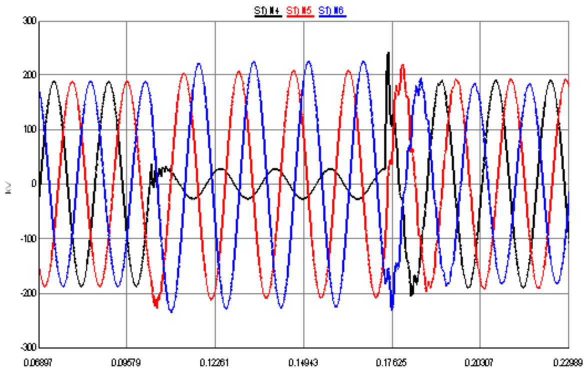
FLORIDA STATE UNIVERSITY 1851

CENTER FOR ADVANCED POWER SYSTEMS FSU

WHAT IS EMT SIMULATION?

Type of Simulation	Load Flow	Transient Stability Analysis (TSA)	Electromagnetic Transient (EMT)
Typical timestep	Single solution	~ 8 ms	~ 2 - 50 μs
Output	Magnitude and angle	Magnitude and angle	Instantaneous values
Frequency range	Nominal frequency	Nominal and off-nominal frequency	0 – 3 kHz (<15 kHz)





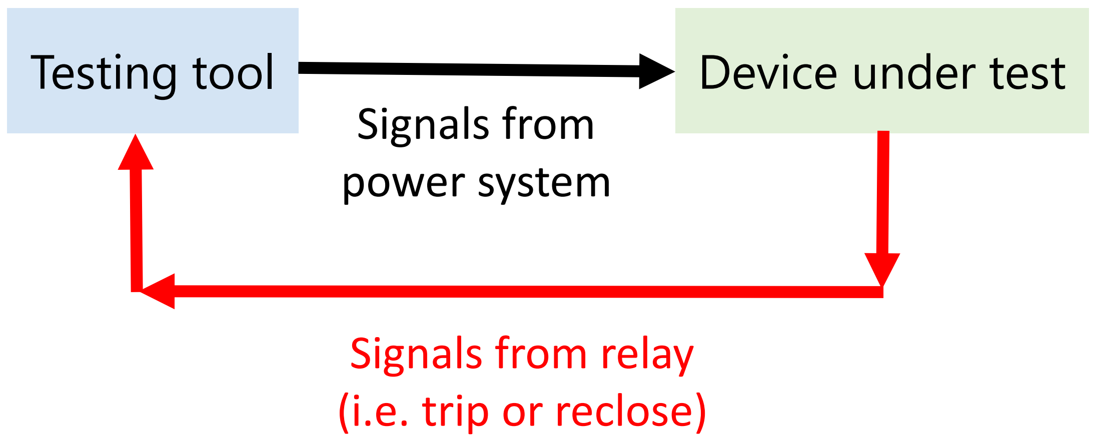
WHAT IS REAL TIME?

- **Real time it takes for an event to occur = Simulation time of an event.**
  - E.g. 3 cycle fault for 60Hz system = 0.05 seconds. RTDS simulates this fault in real time i.e. 0.05 seconds.
  - Non-real-time simulations will simulate events faster or slower than real time depending on case complexity.
- Parallel processing required for practical systems.
- Measured by counting clock cycles.
- **Values updated each timestep.**
  - All calculations and servicing IO completed within a timestep.
  - Every timestep has same duration and is completed in real time.

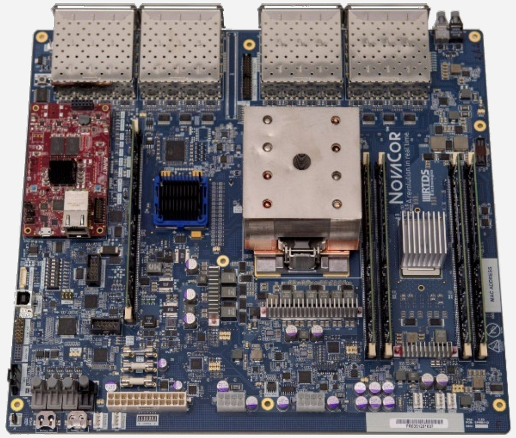
ADVANTAGES OF CLOSED-LOOP TESTING

Real time operation is what allows us to connect physical devices in a **closed loop** with the simulated environment

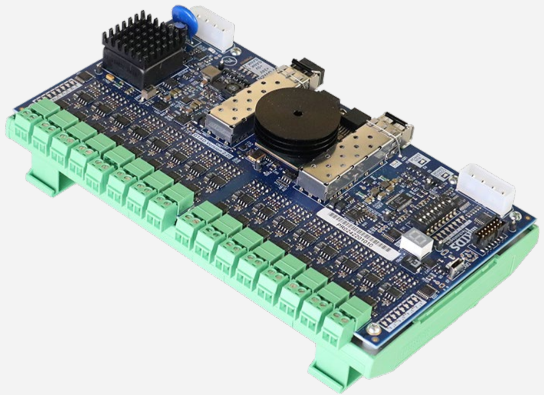
- Test continues after the action of the protection/control device, showing dynamic response of the system
- Test multiple devices (and entire schemes) at once
- Much more detailed system representation than open-loop test systems provide (e.g. modelling power electronics)
- No need to bring equipment out of service

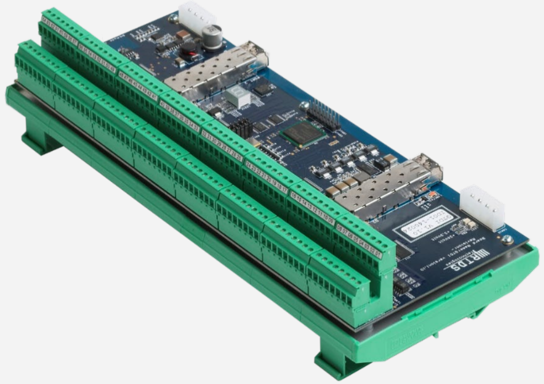


MAINTAINING REAL TIME: HARDWARE



- Parallel processing platform based on a IBM™'s POWER8® multicore processor
- Custom integrated, runs bare-metal (no OS)
- Modular design
- Main interface is through user-friendly software
- I/O to connect physical devices





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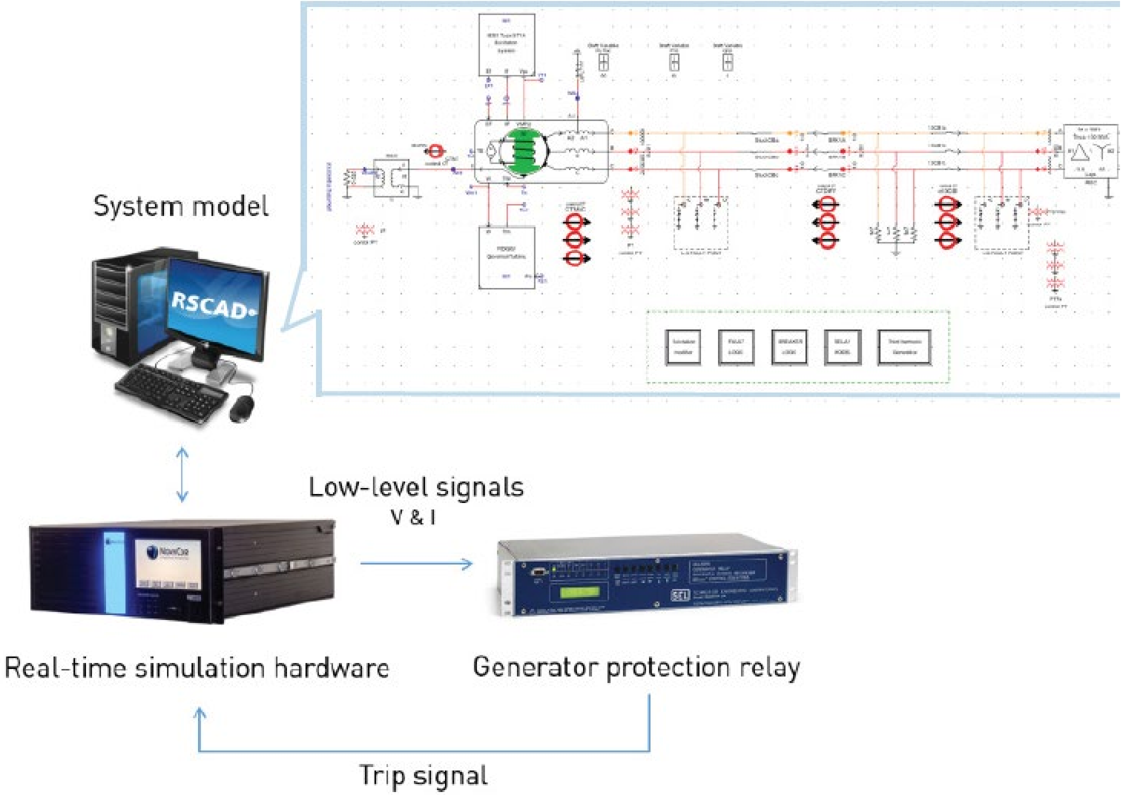
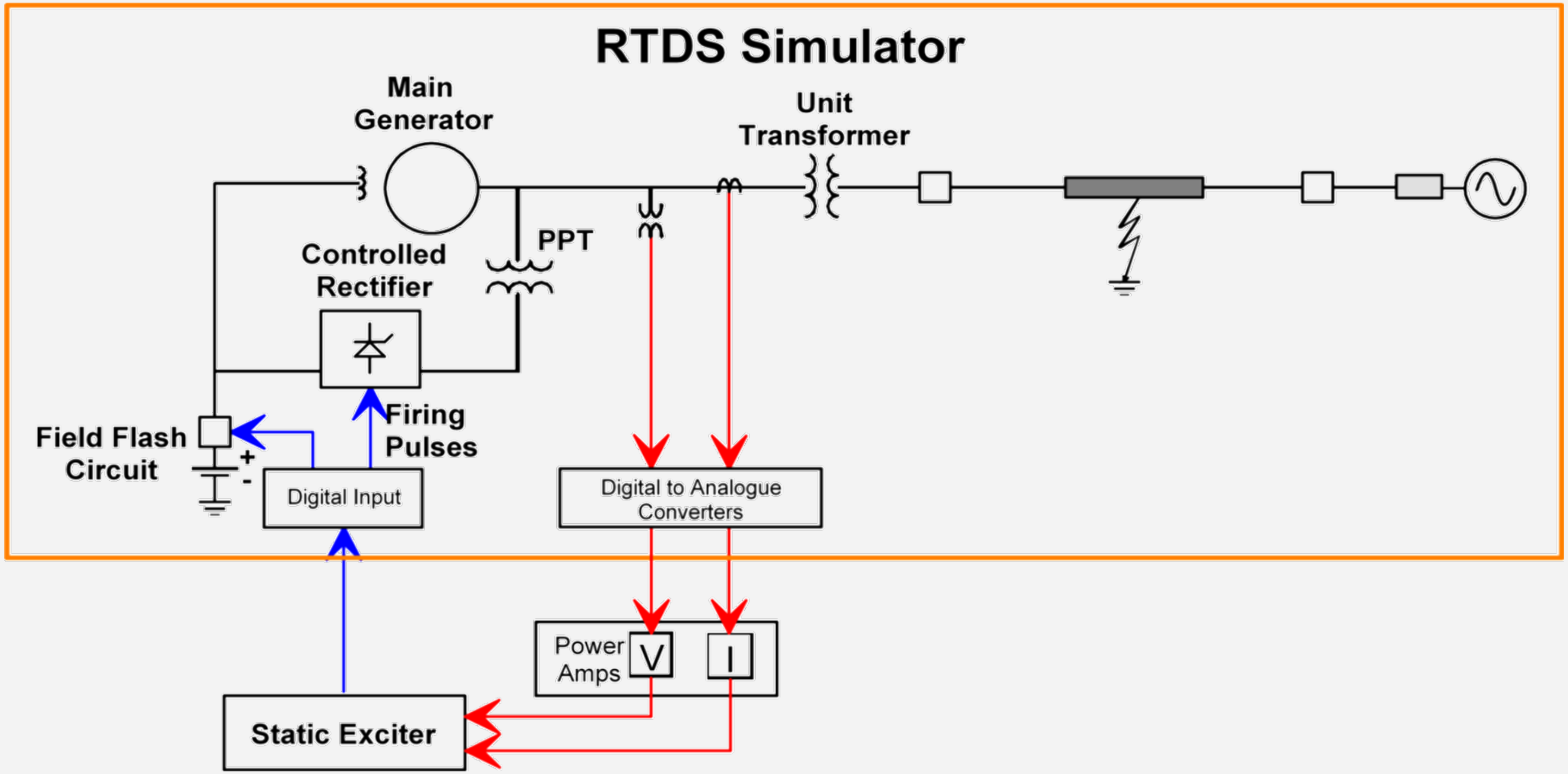
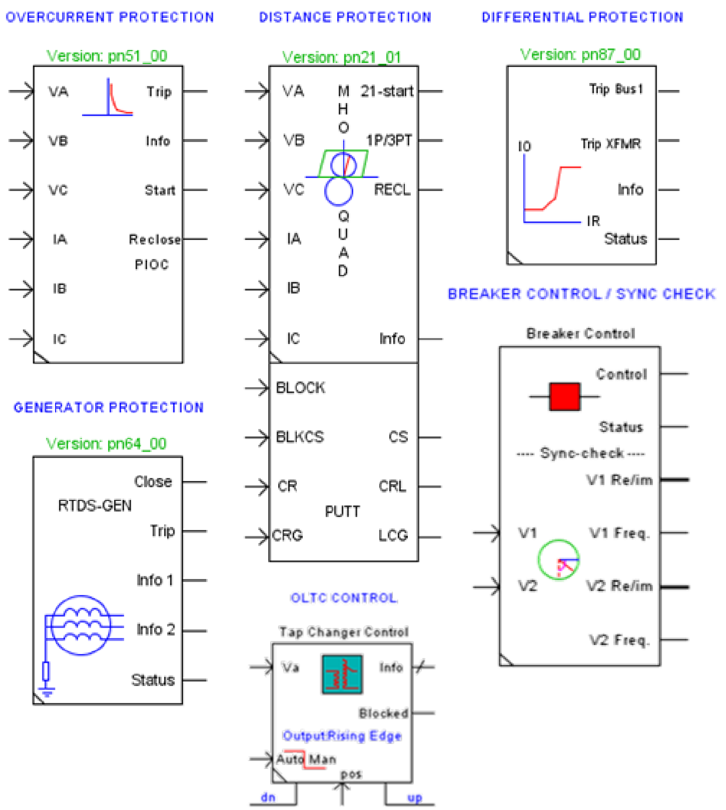
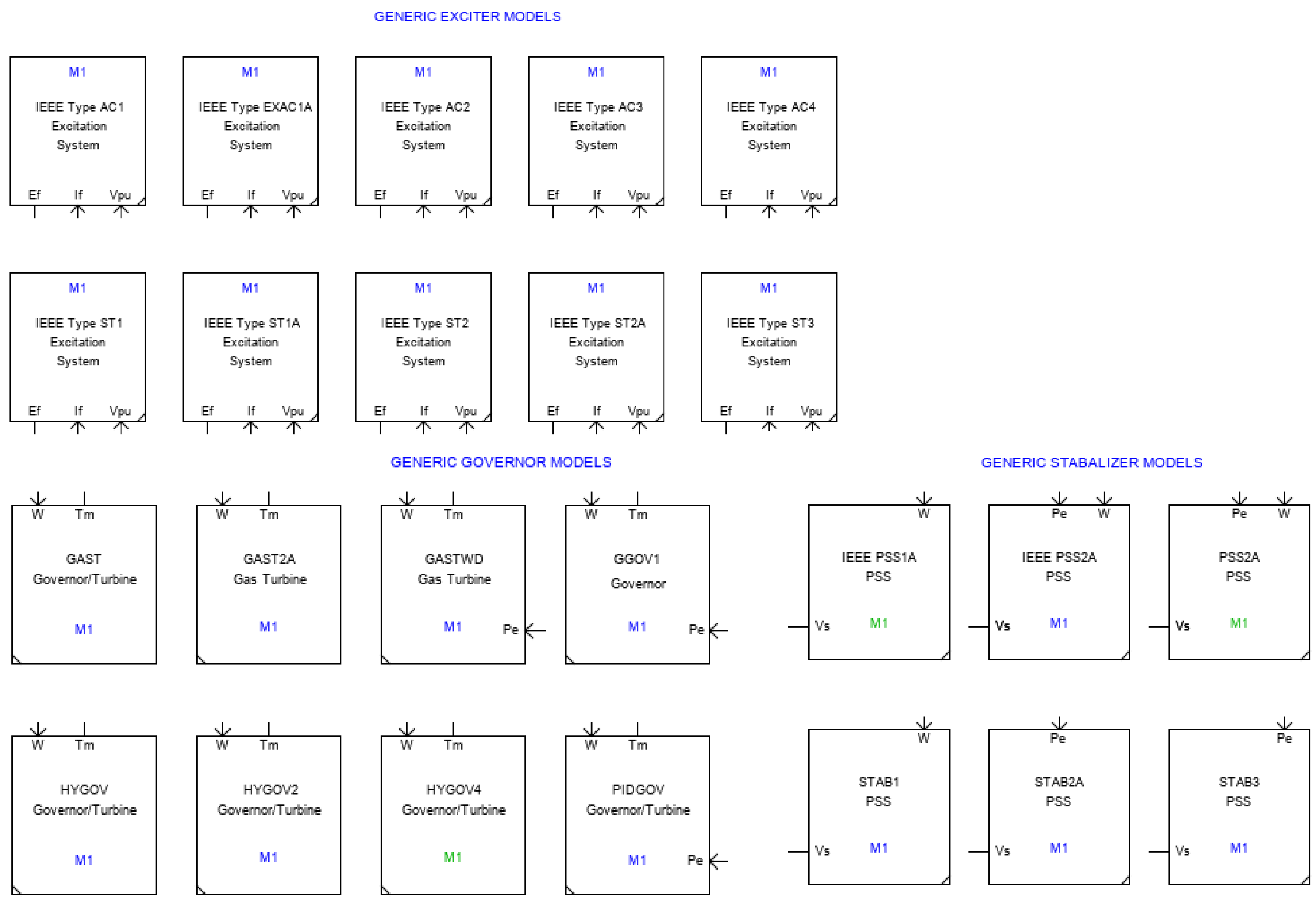


EXCITER TESTING EXAMPLE

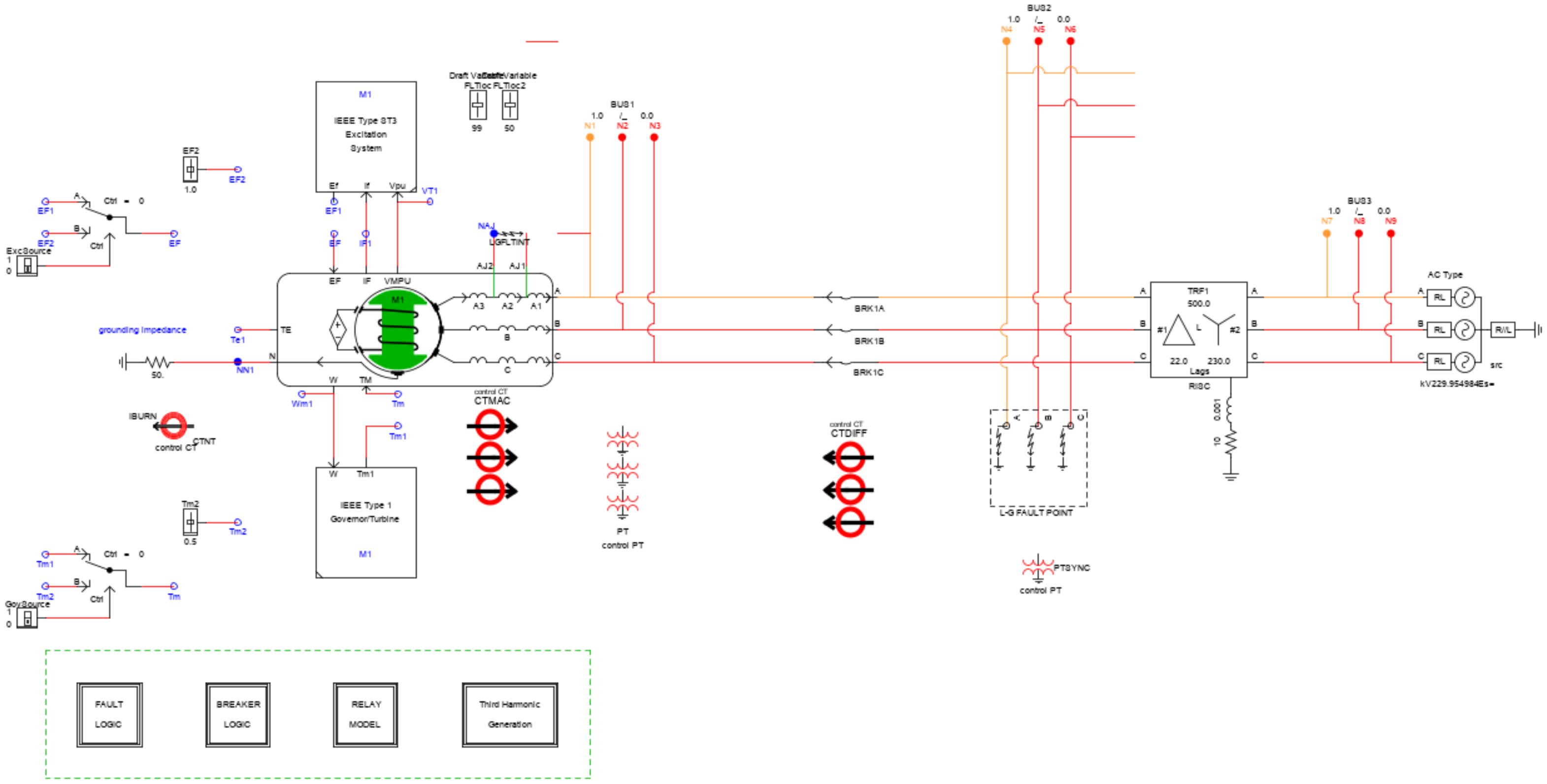


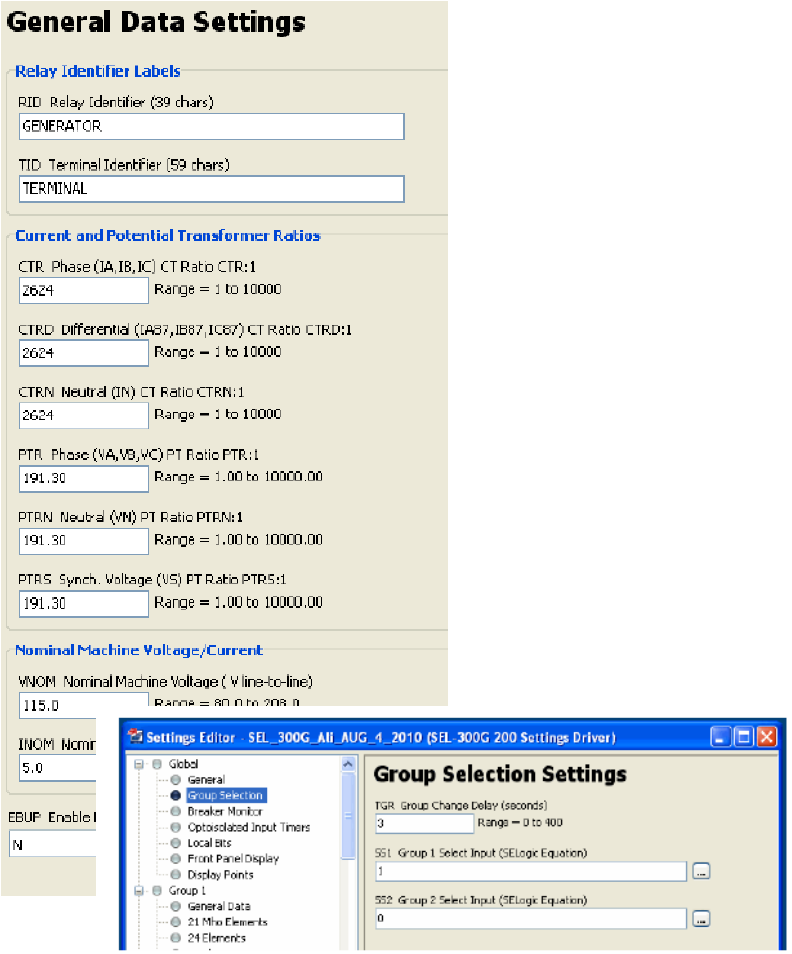
SIMULATED PROTECTION AND CONTROL





RSCAD SAMPLE CASE: SEL-300G TESTING





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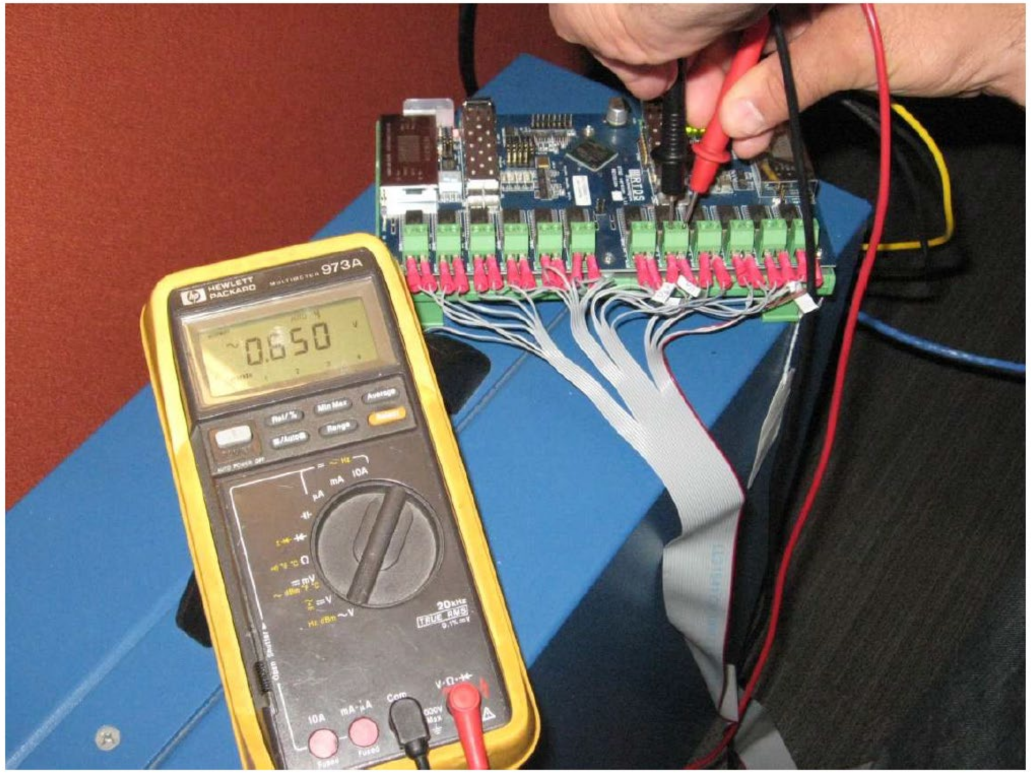
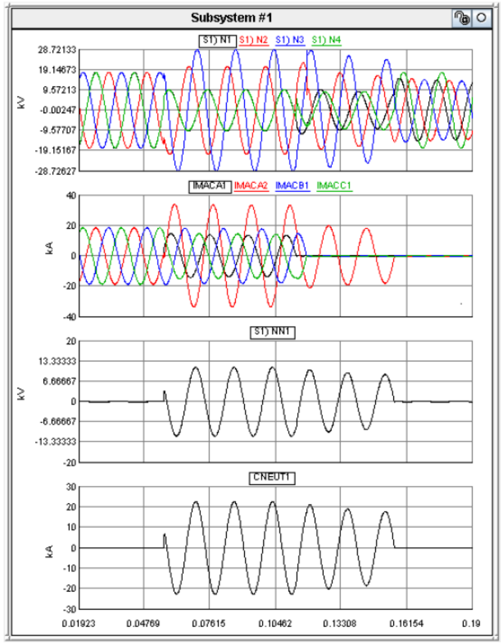
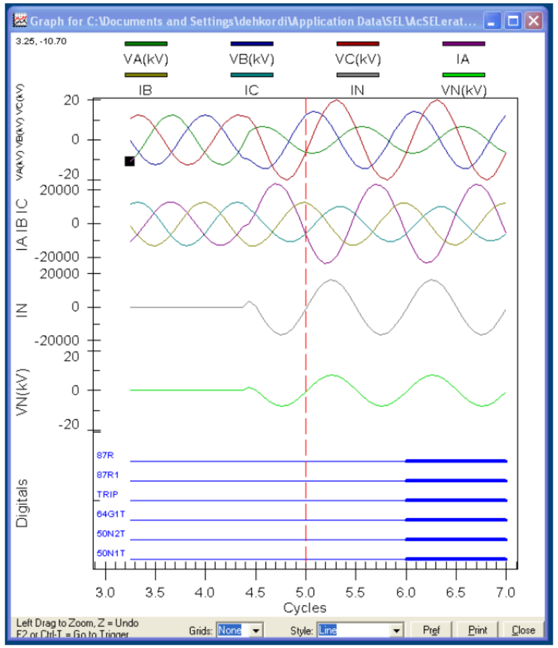
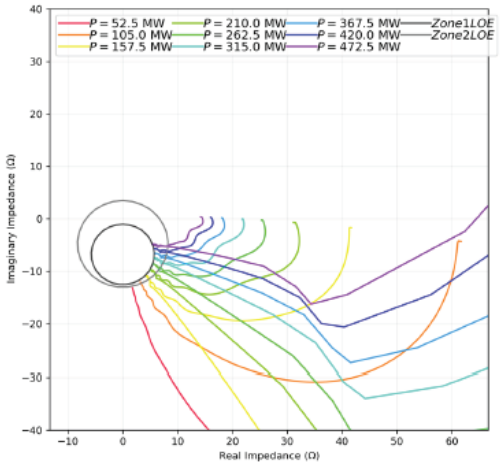


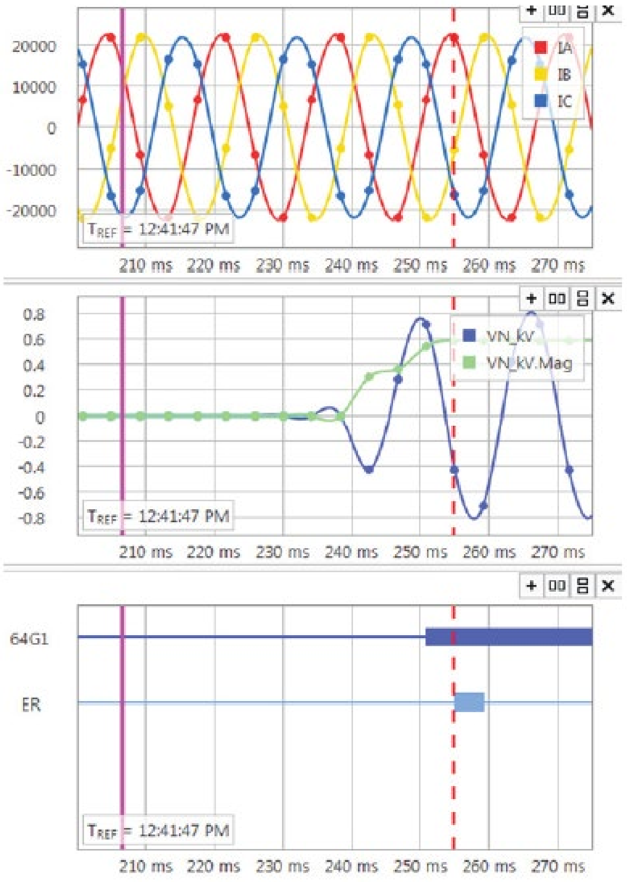




BC HYDRO

- Improved relay commissioning process with HIL testing
- Diagnosing generator and transformer protection issues such as diff. element tripping due to severe CT saturation on transformer energization
- Replicating historical events
- Batch mode testing





Thank you!

Please contact marketing@rtds.com with any additional questions.

Attendees will receive an email with the webinar recording and Q&A document in the next few days.

Electric Machine Models in the RTDS Simulator and their Applications

Part I: Generator Protection and Control Testing

Ali Dehkordi

Content of the Presentation

RTDS® Simulator

Introduction to the library of electric machine models in RTDS

Demonstration of Generator Protection and Control

RTDS® Simulator

Real-time digital simulation is a fully digital simulation where all calculations required to determine the transient state of the power system and servicing of I/Os are completed within a time interval equal to the simulation time-step.

Simulation results are in synchronism with the real-world clock.

Real-time response is needed for closed-loop testing of equipment

RTDS® Simulator

World's 1st real-time digital HVDC simulator

RTDS development project was carried out by Manitoba HVDC Research Centre.

RTDS Technologies Inc. was created in 1994

RTDS® Simulator

RTDS Clients:

- Electrical power utilities
- Electrical equipment manufacturers
- Research and learning institutions

Company Mandate:

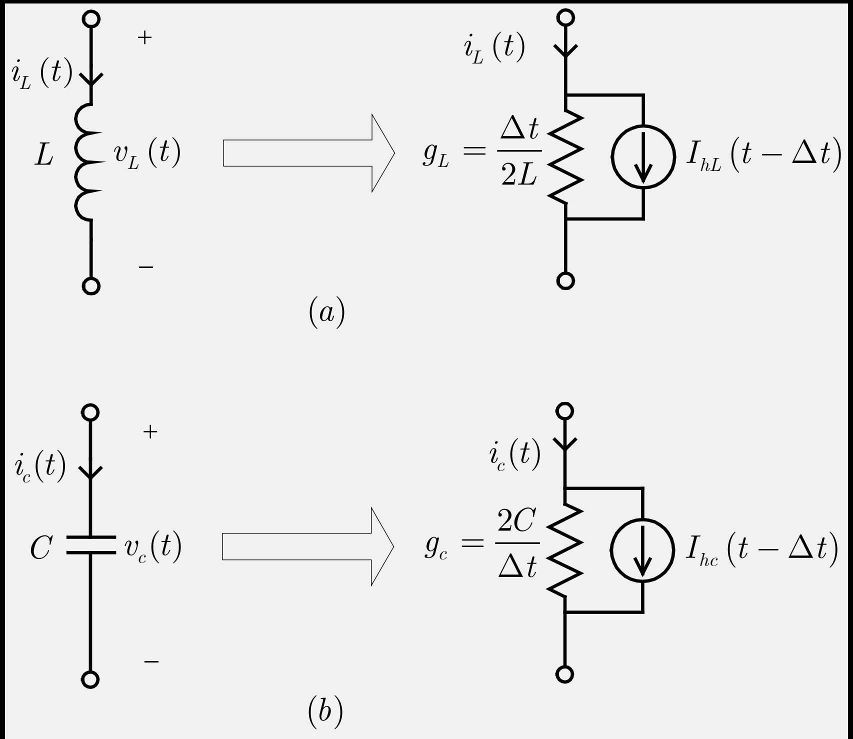
- Continued development of RTDS' hardware, software, library components, and simulation tools
- Marketing and sales
- Training and after sales technical support

Electromagnetic Transients Program (Based on Dommel Algorithm)

Differential equations of the elements are discretized and represented by Norton equivalents resulting in a network of resistances and current sources

Nodal analysis method is used for solving this network.

Sophisticated elements are modeled as current sources.



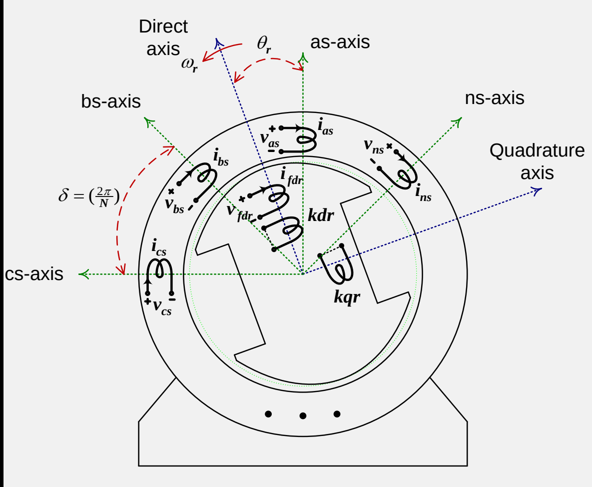
Part I

Introduction to Electric Machine Models in RTDS

Coupled Electric Circuit Approach

Machine is treated as a set of mutually-coupled time-varying inductances.

For an idealized Park machine, d- and q-axes equivalent circuits may be extracted.



$$\begin{pmatrix}\underline{v}_{ab\ldots n_s}\\ \underline{v}_{dq_r}\end{pmatrix} = \begin{pmatrix}[r_s] & [0]\\ [0] & [r_r]\end{pmatrix}\begin{pmatrix}\underline{i}_{ab\ldots n_s}\\ \underline{i}_{dq_r}\end{pmatrix} + \frac{d}{dt}\begin{pmatrix}\underline{\psi}_{ab\ldots n_s}\\ \underline{\psi}_{dq_r}\end{pmatrix}$$

$$\begin{pmatrix}\underline{\psi}_{ab\ldots n_s}\\ \underline{\psi}_{dq_r}\end{pmatrix} = \begin{pmatrix}[L_{ss}] & [L_{sr}]\\ [L_{sr}]^T & [L_{rr}]\end{pmatrix}\begin{pmatrix}\underline{i}_{ab\ldots n_s}\\ \underline{i}_{dq_r}\end{pmatrix}$$

where:

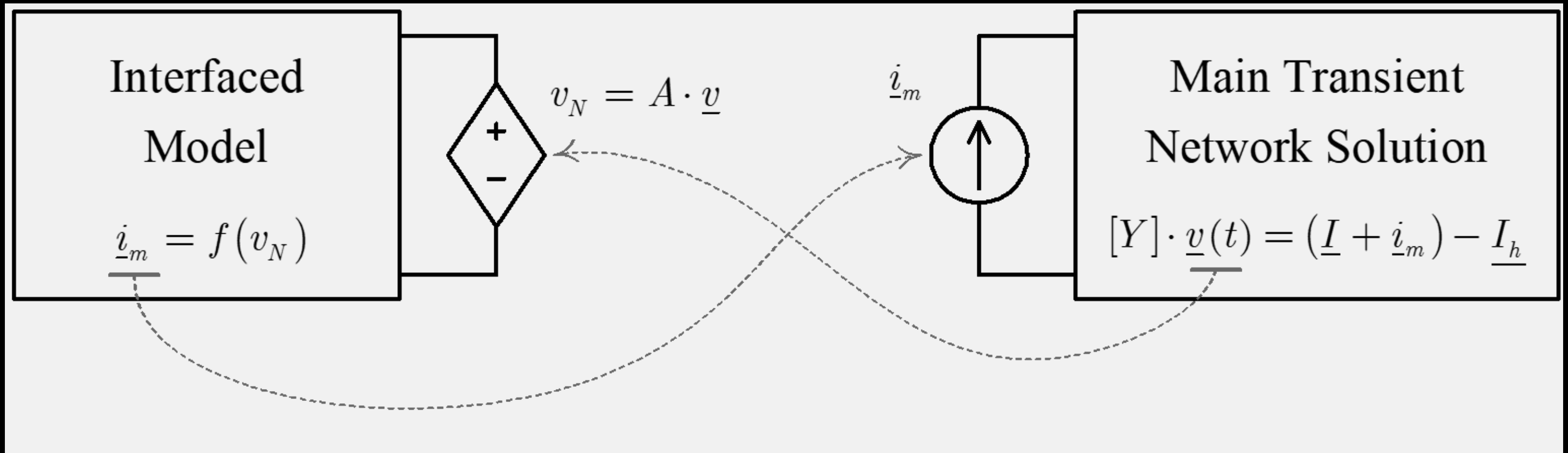
$$\left(\underline{f}_{ab\ldots n_s}\right)^T = \left(f_{as}\ f_{bs} \cdots f_{ns}\right)$$

$$\left(\underline{f}_{dq_r}\right)^T = \left(f_{dr_1}\ f_{dr_2} \cdots f_{qr_1}\ f_{qr_2} \cdots\right)$$

Inclusion of Electric Machine Models into the Network Solution of RTDS

Interface-Based Approach:

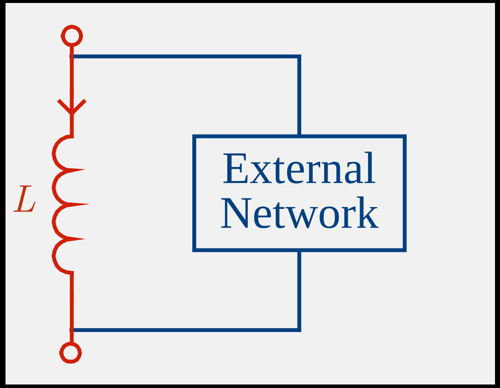
- Advantage: Simple
- Disadvantage: Time-delay effects

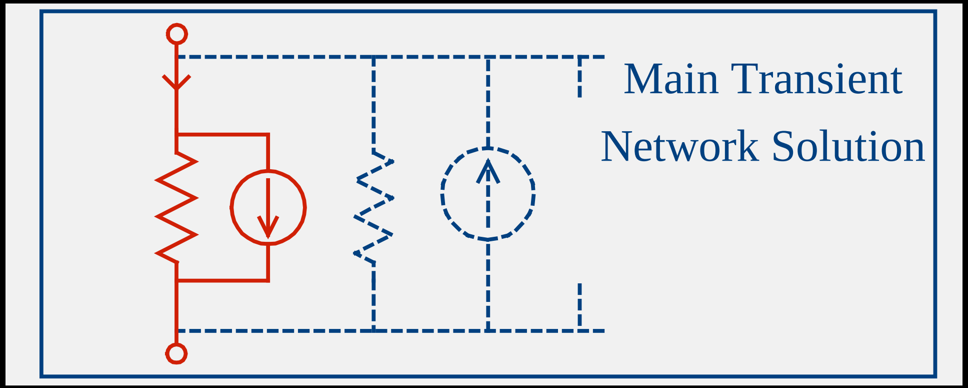


Inclusion of Electric Machine Models into the Network Solution of RTDS

The Embedded Phase-Domain Approach of Modeling Machines in Digital Electromagnetic Transients Simulation:

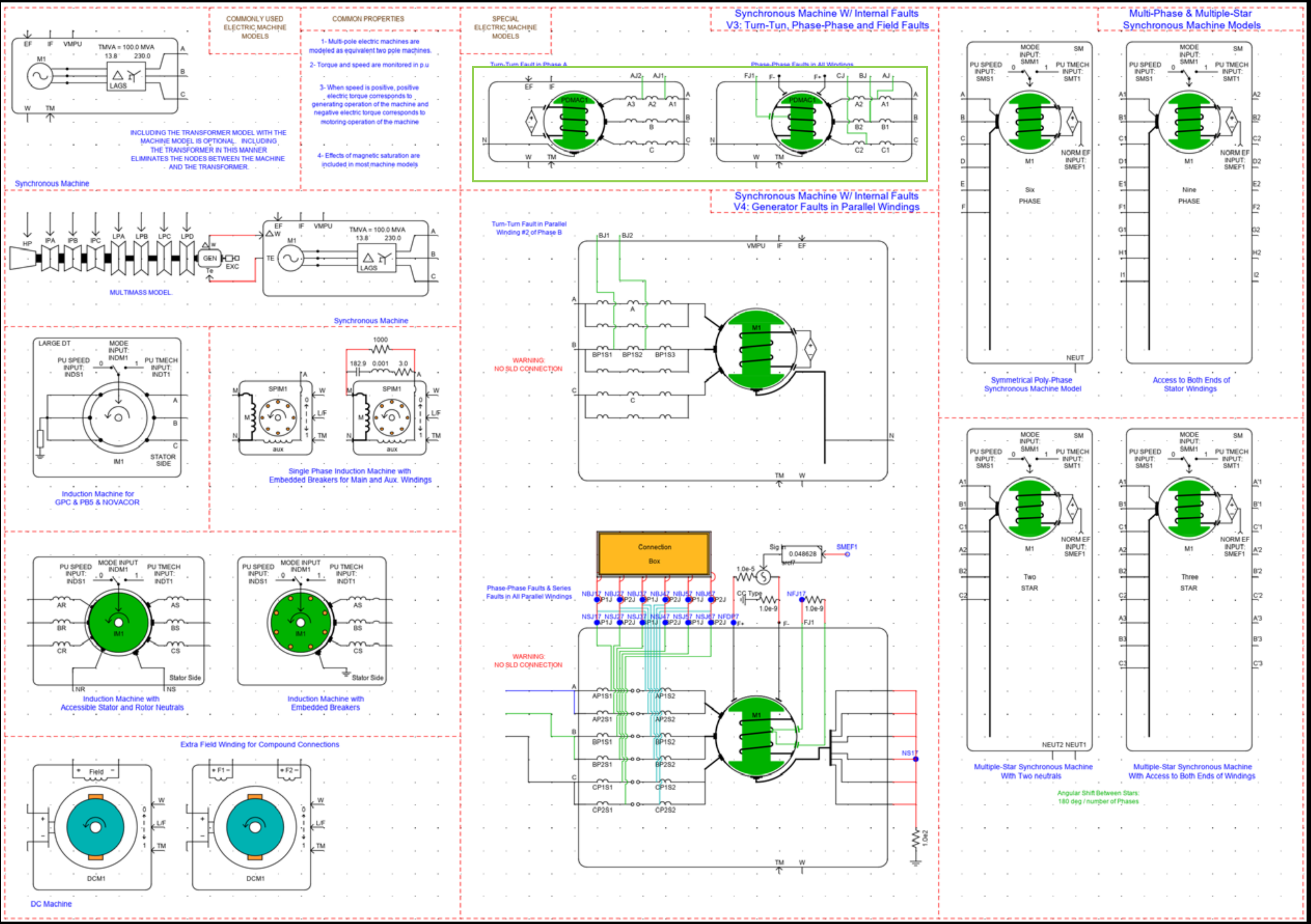
- Modeling the set of mutually coupled time-varying inductors in a similar manner of modeling an inductor in EMT programs
- The network solution is directly involved in solving the differential equations of the machine
- Computationally more extensive, mathematically precise
- Possibility of modeling internal faults





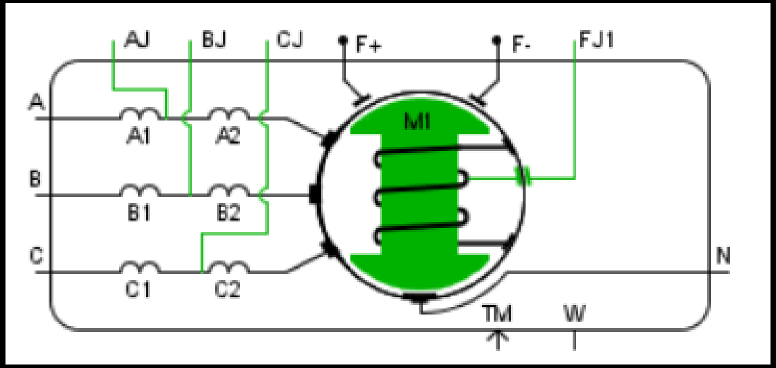
Library of Electric Machines in RTDS

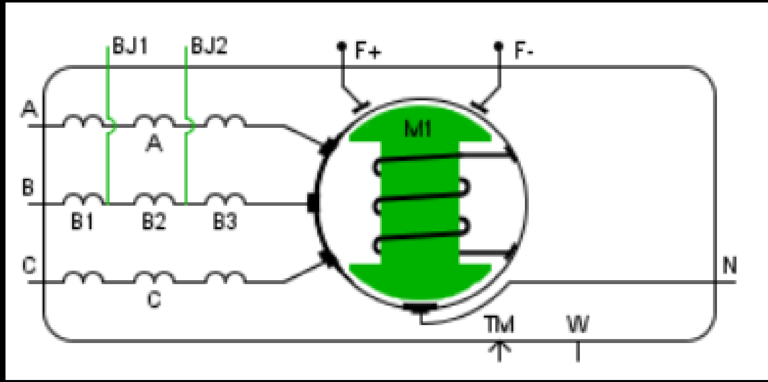
Main timestep & Substep Modules



Faulted Synchronous Machine Model (_rtds_PDSM_FLT_V3), Developed in 2017:

- No Faulted Points
- Two Faulted Points on Stator Phase "A" or "B" or "C"
- Two Faulted Points on the Field Winding
- One Faulted Point on Each one of the Stator Windings and the Field Winding
- For all of the above conditions, users can select the location(s) of the faulted point(s) to be anywhere between 1% - 99% of the winding. Faulted windings currents and voltages can also be monitored.



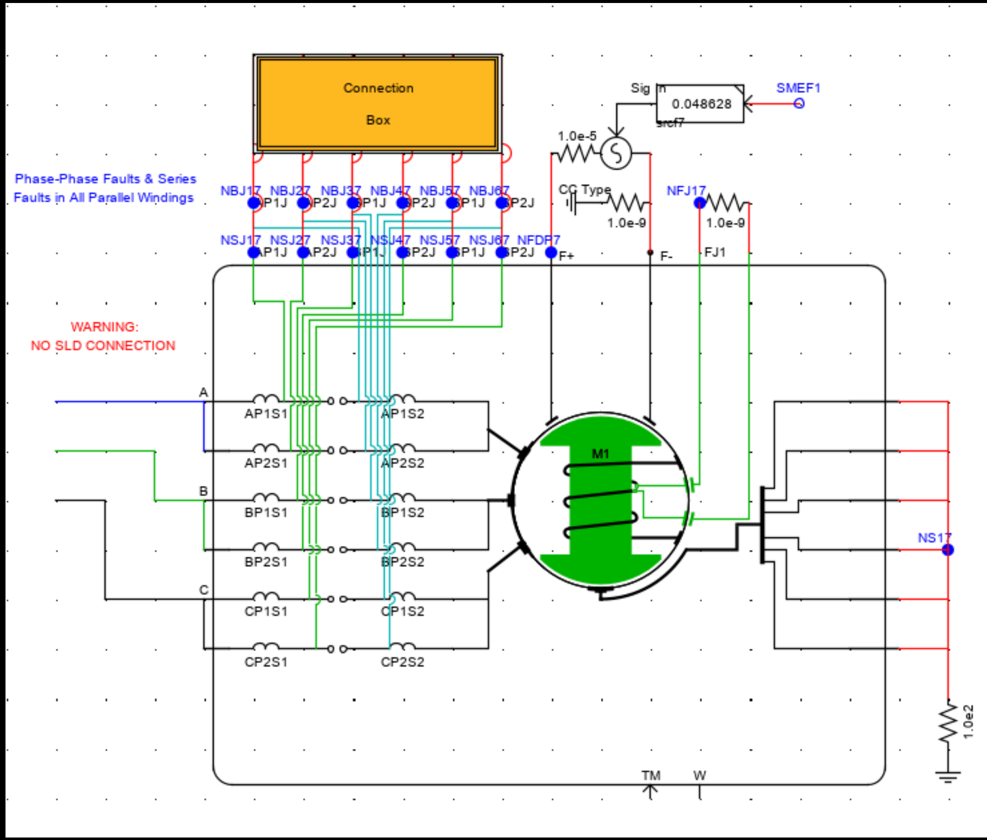


Application: Generator and motor protection: stator turn-turn, phase-phase and phase-ground protection. protection of the field winding.

Library of Electric Machines in RTDS

Faulted Synchronous Machine Model (_rtds_PDSM_FLT_V4), Developed in 2018:

- Inclusion of Parallel Windings
- Possibility of Modeling Series Faults (i.e. faults when the windings open) by allowing access to all ends of sub-windings
- Modeling Machines with Inherent Asymmetry in the Windings



Application: Generator and motor protection: stator turn-turn, phase-phase and phase-ground protection, protection of the field winding, protection of parallel windings and series faults.

Part II

Demonstration of Generator Protection and Excitation

Thank you!

www.rtds.com

Contact us: dehkordi@rtds.com