

**WEBINAR**

**ELECTRIC MACHINE  
MODELS FOR THE RTDS  
SIMULATOR**



**APPLICATION: GENERATOR  
PROTECTION AND  
CONTROL TESTING**



[RTDS.COM](http://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

**SIEMENS**



**B** Basler Electric

**Schneider**  
Electric

**ABB**

**SEL** SCHWEITZER  
ENGINEERING  
LABORATORIES

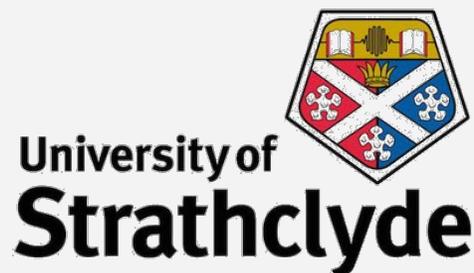
# WORLDWIDE USER BASE

## Utilities



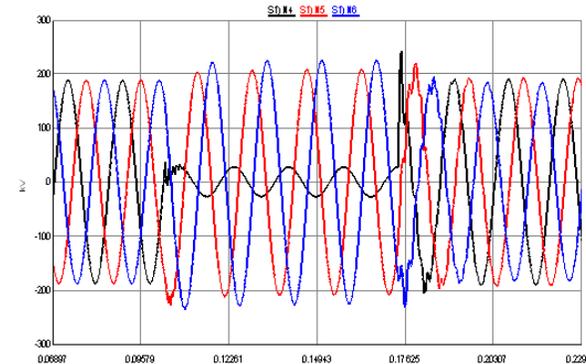
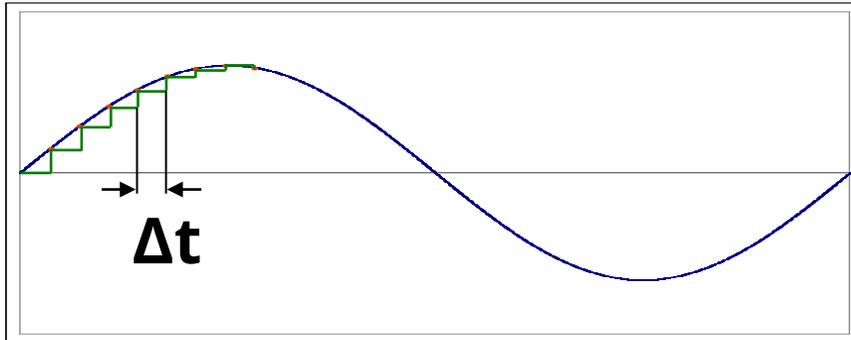
# WORLDWIDE USER BASE

## Research and educational institutions



# WHAT IS EMT SIMULATION?

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



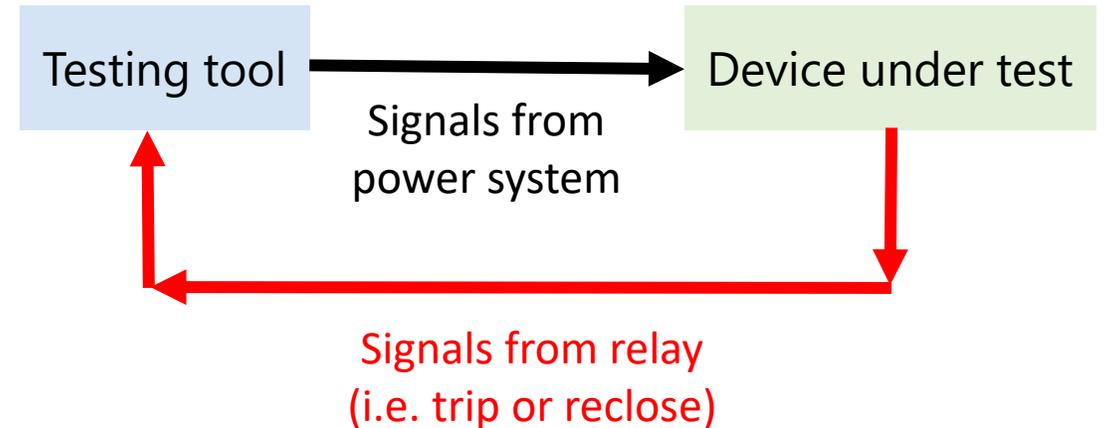
# WHAT IS REAL TIME?

- **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.

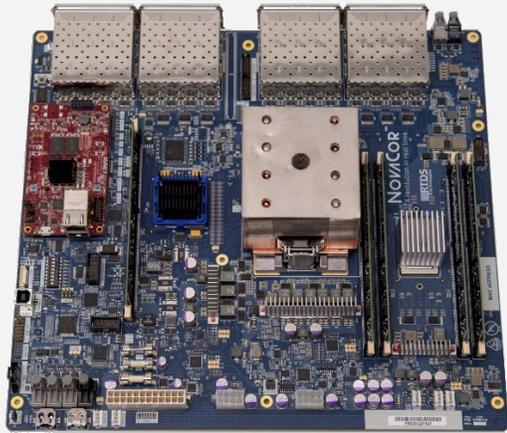
# ADVANTAGES OF CLOSED-LOOP TESTING

**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



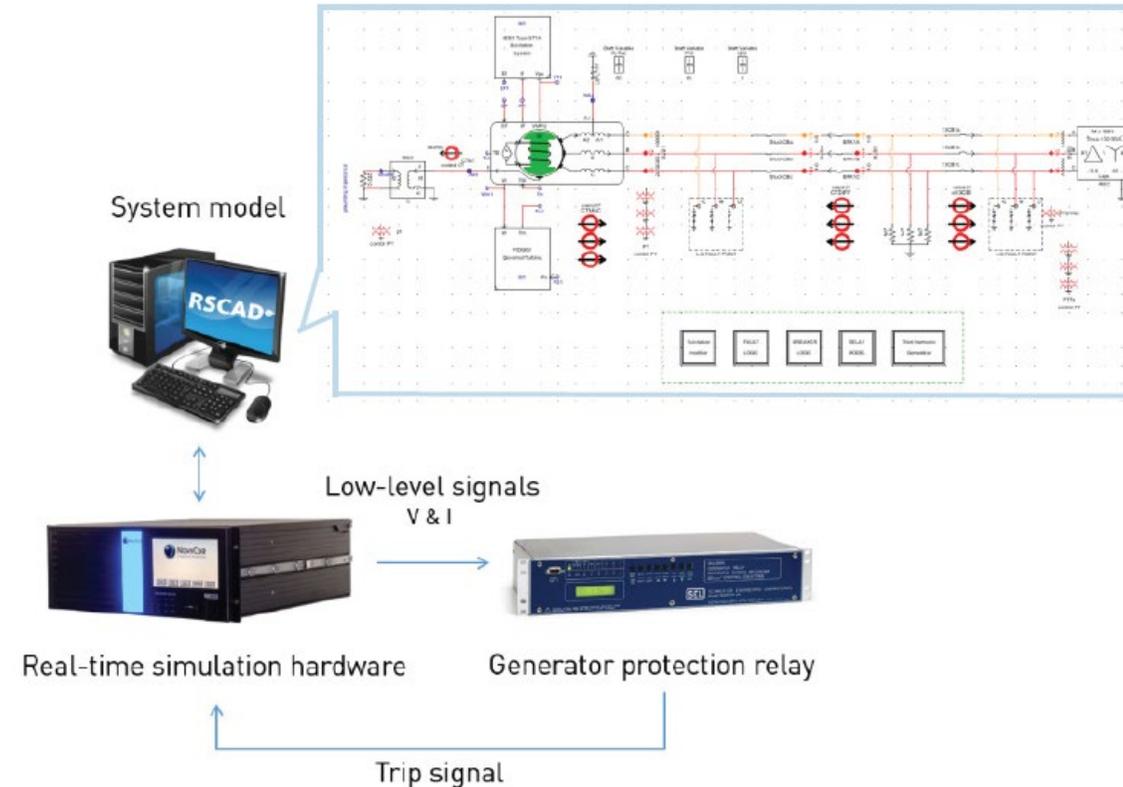
- Parallel processing platform based on a IBM™'s POWER8® multicore processor
- Custom integrated, runs bare-metal (no OS)
- Modular design
- Main interface is through user-friendly software
- I/O to connect physical devices



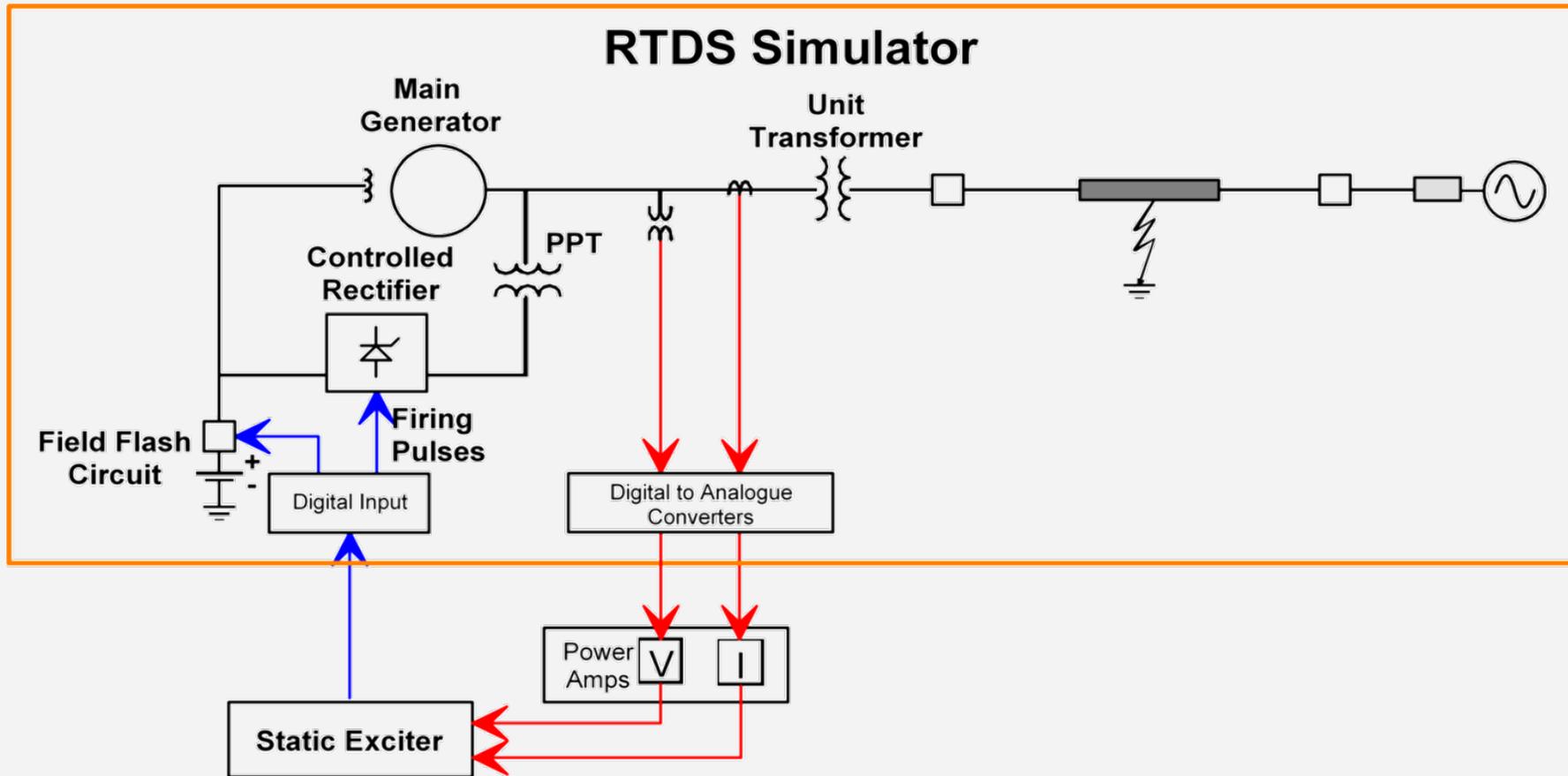
# ADVANTAGES OF CLOSED-LOOP TESTING

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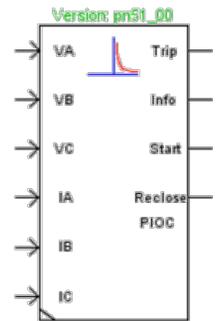


# EXCITER TESTING EXAMPLE

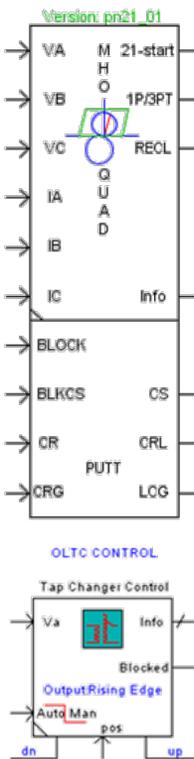


# SIMULATED PROTECTION AND CONTROL

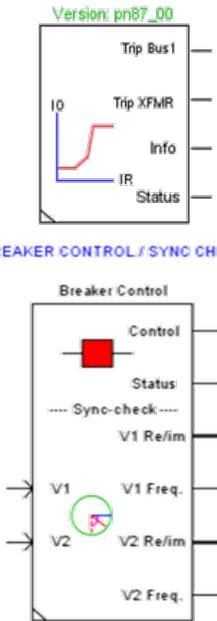
## OVERCURRENT PROTECTION



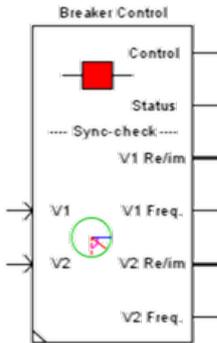
## DISTANCE PROTECTION



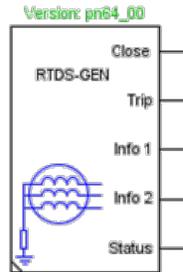
## DIFFERENTIAL PROTECTION



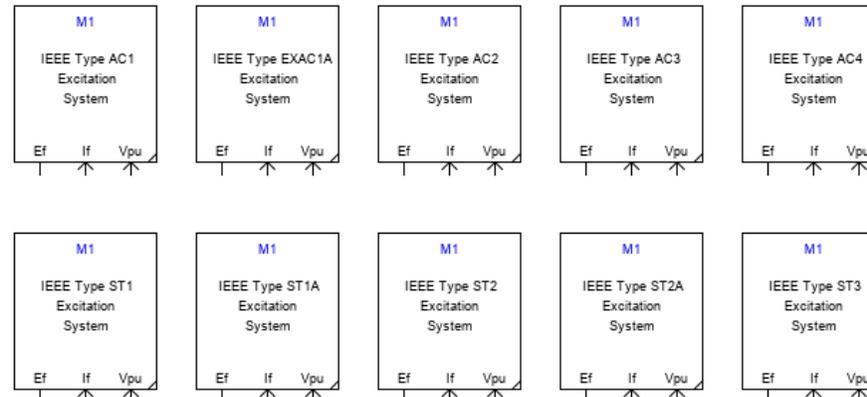
## BREAKER CONTROL / SYNC CHECK



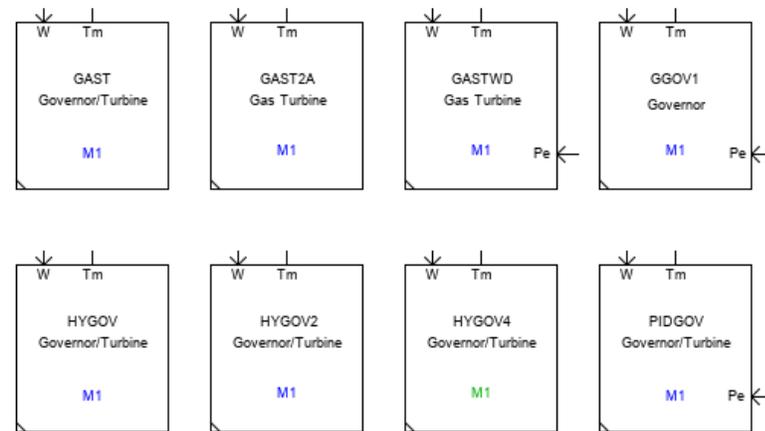
## GENERATOR PROTECTION



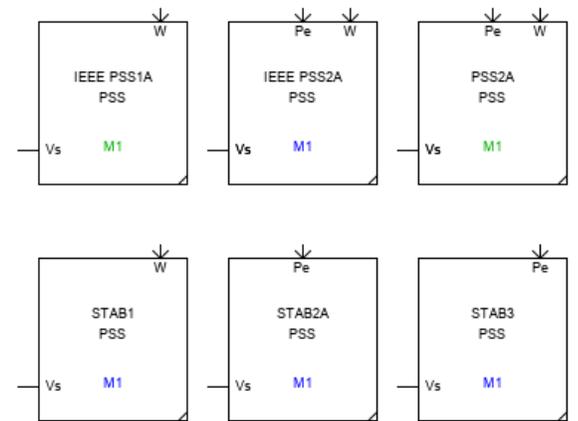
## GENERIC EXCITER MODELS



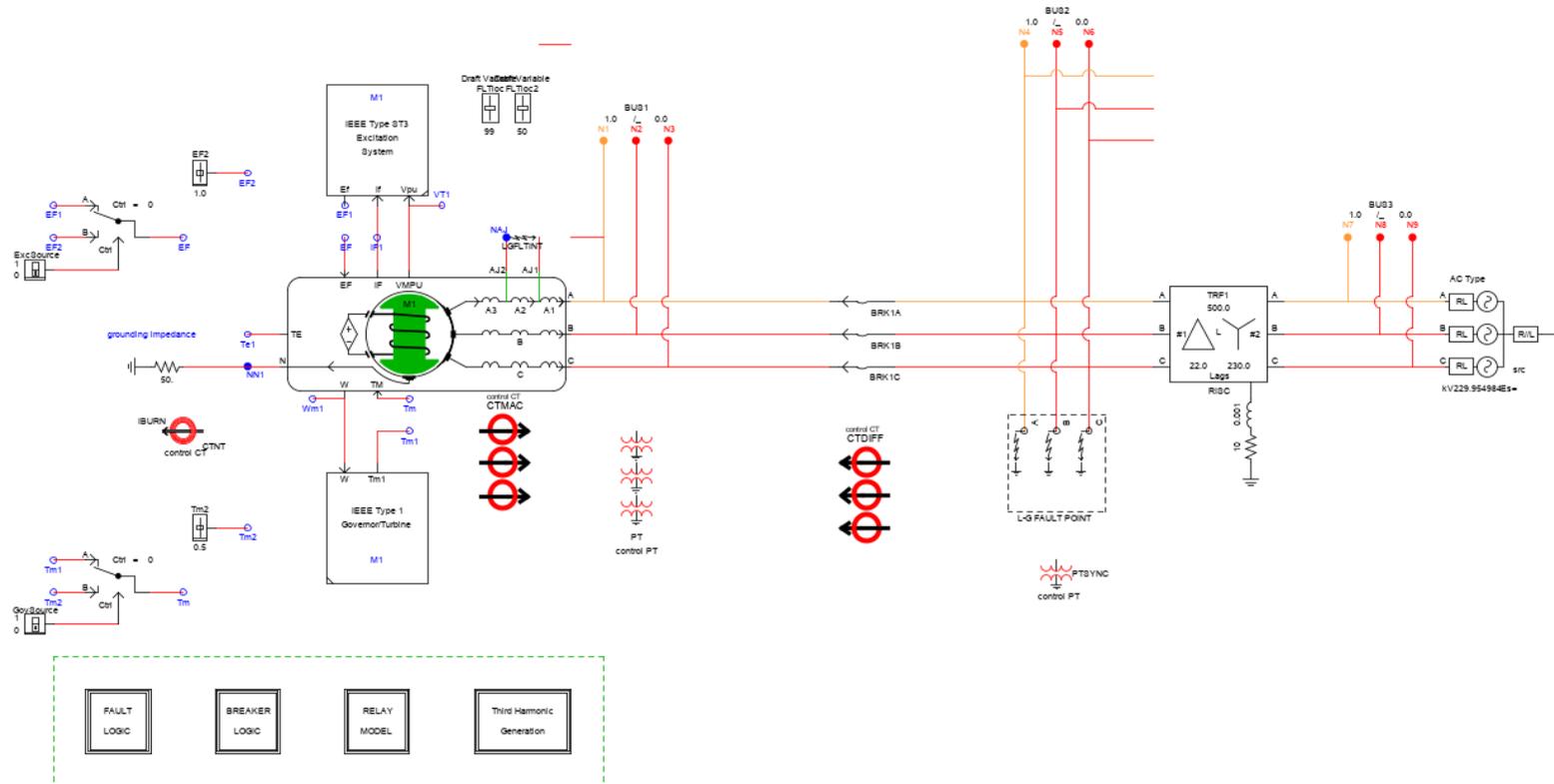
## GENERIC GOVERNOR MODELS



## GENERIC STABILIZER MODELS



# RSCAD SAMPLE CASE: SEL-300G TESTING



## General Data Settings

### Relay Identifier Labels

RID Relay Identifier (39 chars)

TID Terminal Identifier (59 chars)

### Current and Potential Transformer Ratios

CTR Phase (IA,IB,IC) CT Ratio CTR:1  
 Range = 1 to 10000

CTRD Differential (IA37,IB87,IC87) CT Ratio CTRD:1  
 Range = 1 to 10000

CTRN Neutral (IN) CT Ratio CTRN:1  
 Range = 1 to 10000

PTR Phase (VA,VB,VC) PT Ratio PTR:1  
 Range = 1.00 to 10000.00

PTRN Neutral (VN) PT Ratio PTRN:1  
 Range = 1.00 to 10000.00

PTRS Synch. Voltage (V5) PT Ratio PTRS:1  
 Range = 1.00 to 10000.00

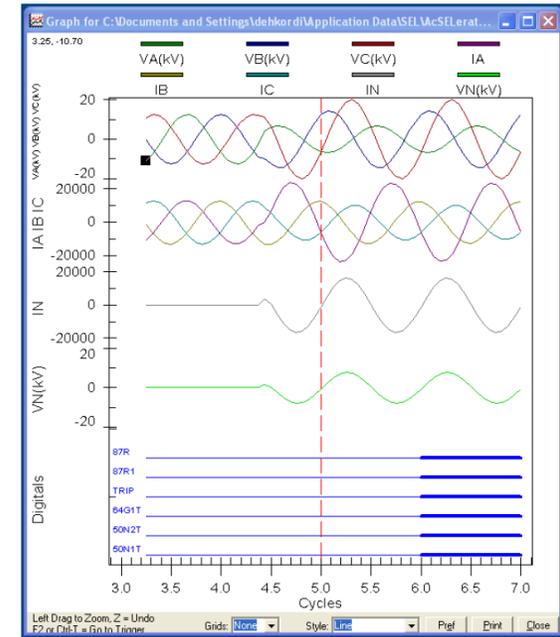
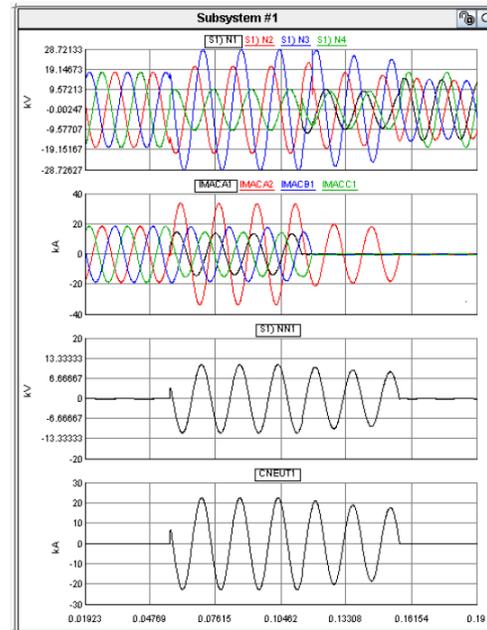
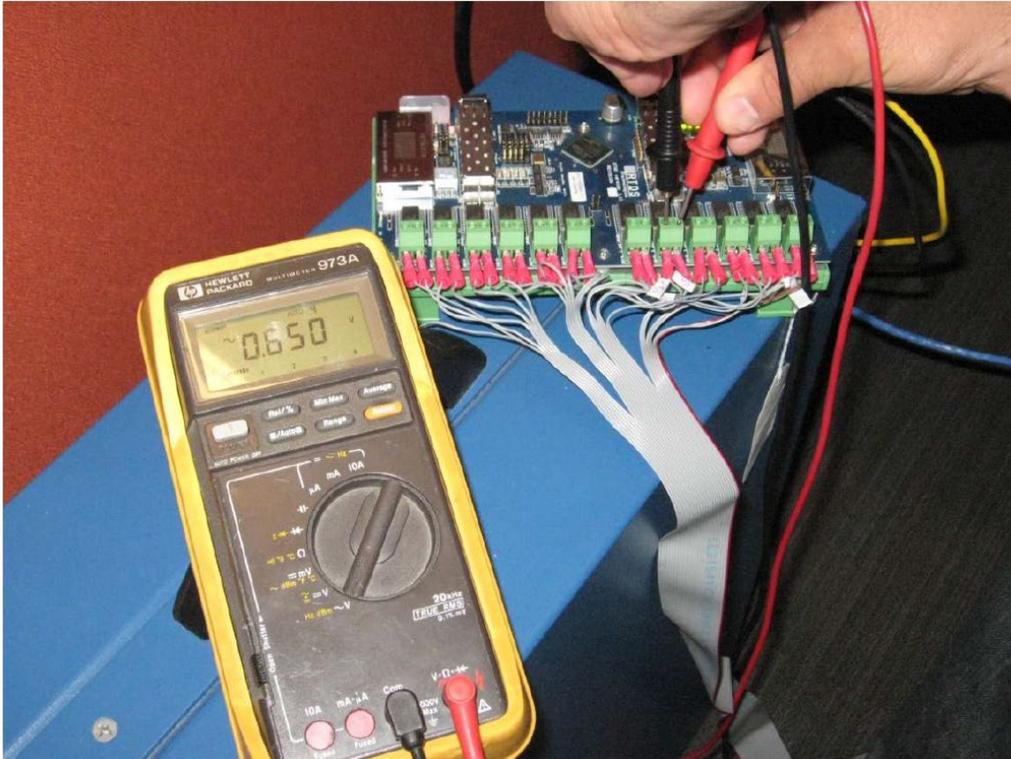
### Nominal Machine Voltage/Current

WNOM Nominal Machine Voltage (V line-to-line)  
 Range = 80.0 to 208.0

INOM Ncmr

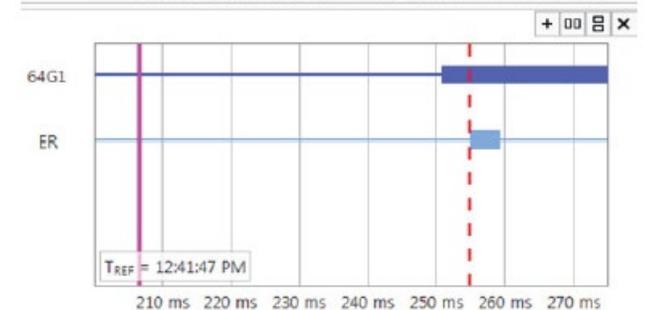
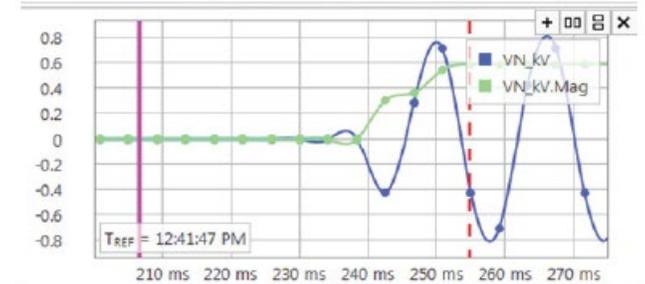
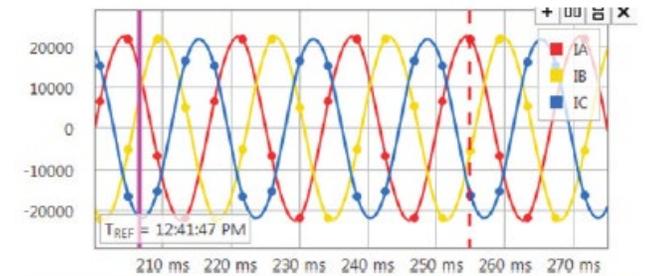
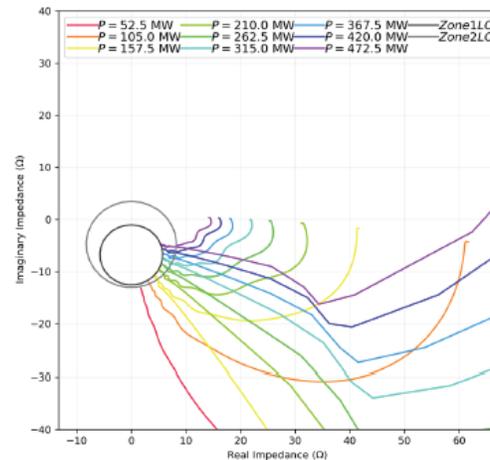
EBUP Enable

# RSCAD SAMPLE CASE: SEL-300G TESTING



# 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](mailto: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.



RTDS.COM



# Electric Machine Models in the RTDS Simulator and their Applications

*Part I: Generator Protection  
and Control Testing*

Ali Dehkordi





# Content of the Presentation

## RTDS<sup>®</sup> 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 1<sup>st</sup> 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

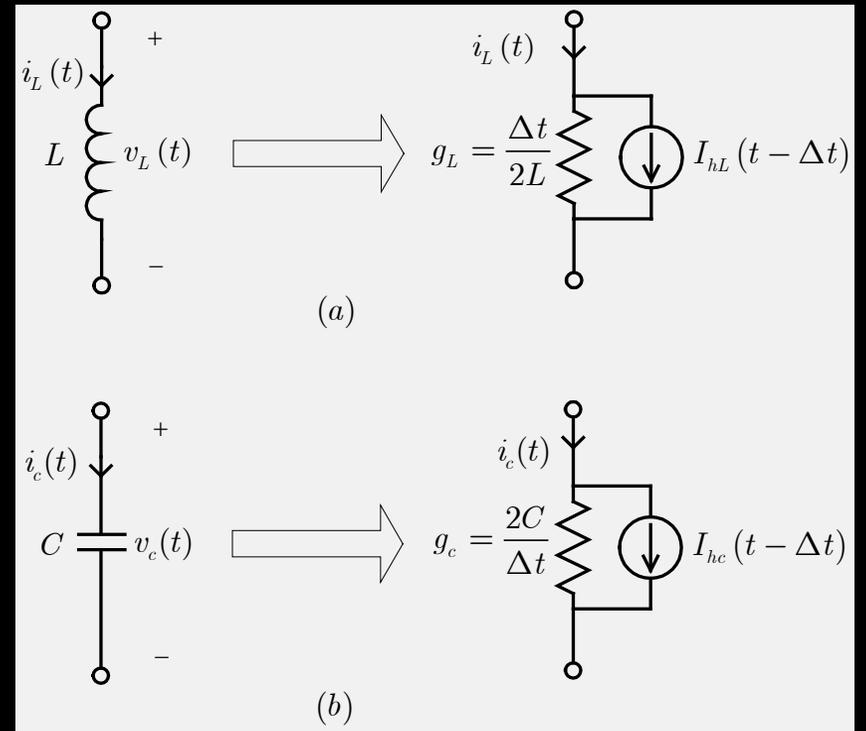


# Electromagnetic Transients Program (Based on Dommel Algorithm)

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.





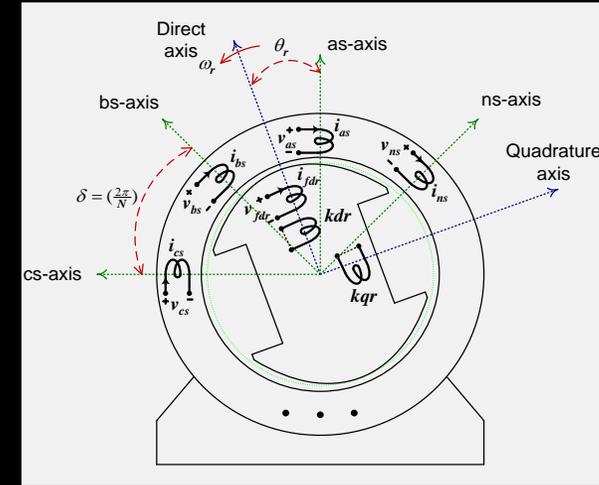
# Part I

## 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.



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

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

where:

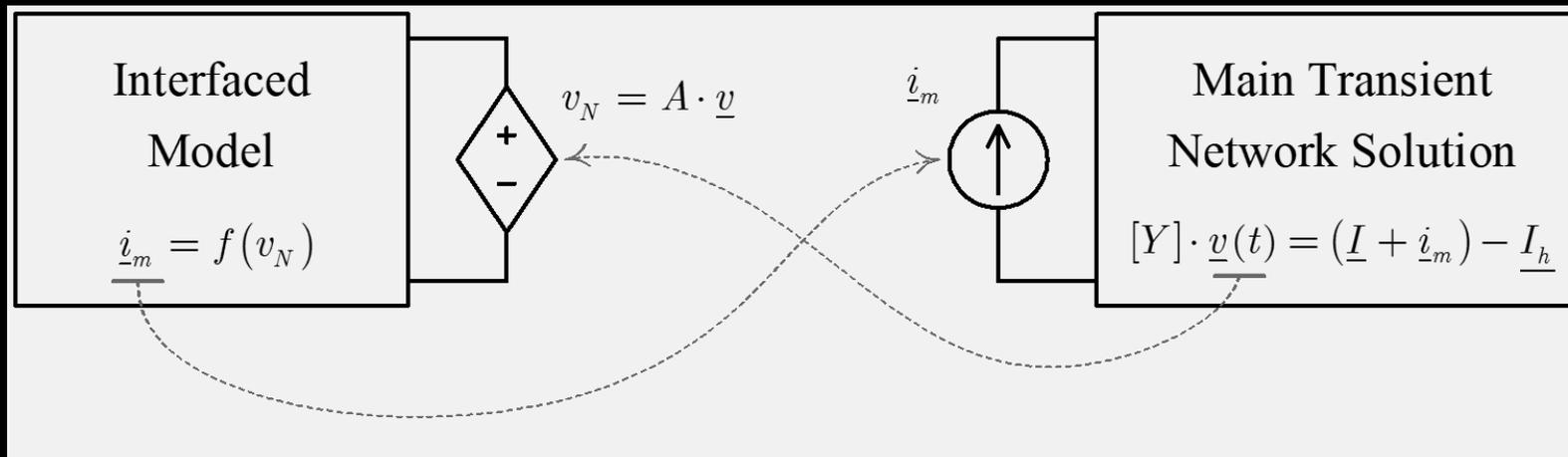
$$\begin{pmatrix} \underline{f}_{ab\dots n_s} \end{pmatrix}^T = (f_{as} \ f_{bs} \ \dots \ f_{ns})$$

$$\begin{pmatrix} \underline{f}_{dq_r} \end{pmatrix}^T = (f_{dr_1} \ f_{dr_2} \ \dots \ f_{qr_1} \ f_{qr_2} \ \dots)$$

# Inclusion of Electric Machine Models into the Network Solution of RTDS

## Interface-Based Approach:

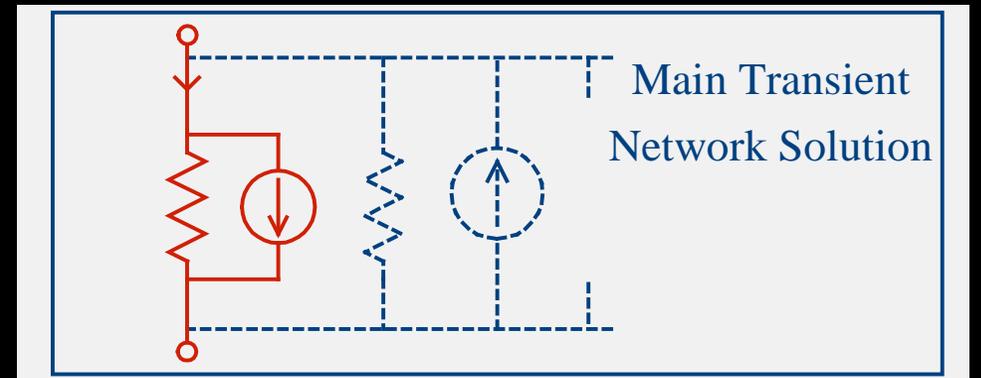
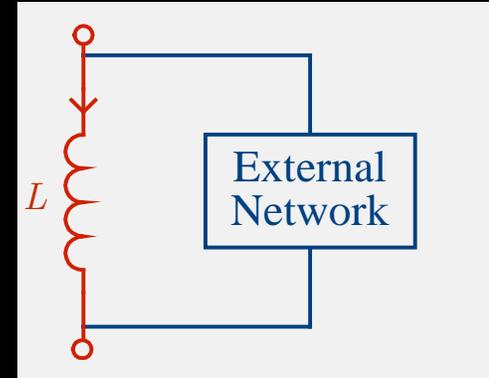
- Advantage: Simple
- Disadvantage: Time-delay effects



# 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

**COMMONLY USED ELECTRIC MACHINE MODELS**

**Synchronous Machine**

INCLUDING THE TRANSFORMER MODEL WITH THE MACHINE MODEL IS OPTIONAL. INCLUDING THE TRANSFORMER IN THIS MANNER ELIMINATES THE NODES BETWEEN THE MACHINE AND THE TRANSFORMER.

**COMMON PROPERTIES**

- 1- Multi-pole electric machines are modeled as equivalent two pole machines.
- 2- Torque and speed are monitored in p.u.
- 3- When speed is positive, positive electric torque corresponds to generating operation of the machine and negative electric torque corresponds to motoring operation of the machine.
- 4- Effects of magnetic saturation are included in most machine models.

**SPECIAL ELECTRIC MACHINE MODELS**

**Synchronous Machine W/ Internal Faults V3: Turn-Turn, Phase-Phase and Field Faults**

**Synchronous Machine W/ Internal Faults V4: Generator Faults in Parallel Windings**

**Multi-Phase & Multiple-Star Synchronous Machine Models**

**Symmetrical Poly-Phase Synchronous Machine Model**

**Access to Both Ends of Stator Windings**

**Multiple-Star Synchronous Machine With Two neutrals**

**Multiple-Star Synchronous Machine With Access to Both Ends of Windings**

Angular Shift Between Stars: 180 deg / number of Phases

**Single Phase Induction Machine with Embedded Breakers for Main and Aux. Windings**

**Induction Machine for GPC & PBS & NOVACOR**

**Induction Machine with Accessible Stator and Rotor Neutrals**

**Induction Machine with Embedded Breakers**

**Extra Field Winding for Compound Connections**

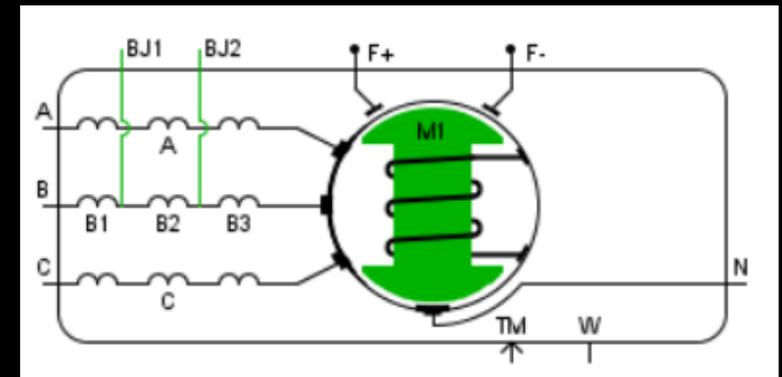
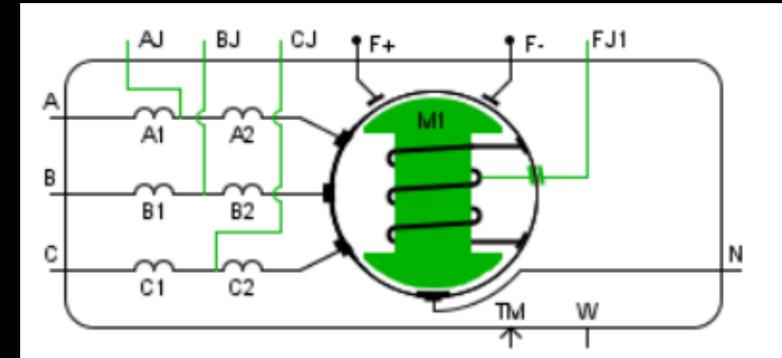
**DC Machine**

# Library of Electric Machines in RTDS

## 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.

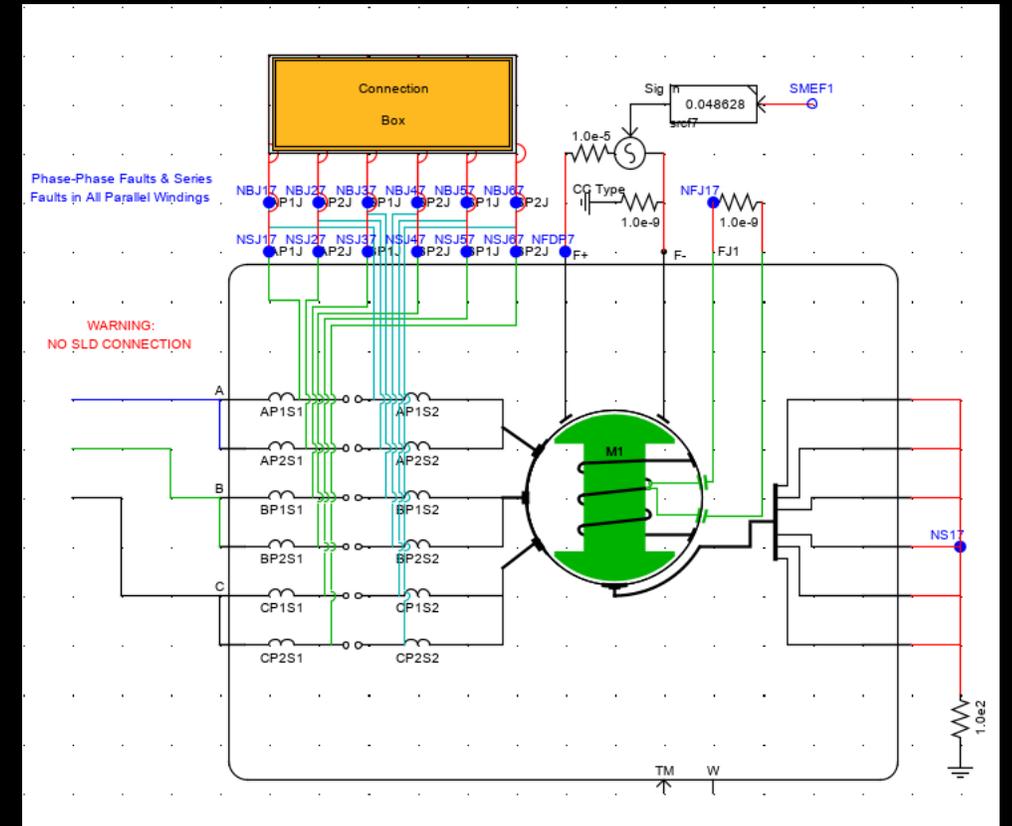


# Library of Electric Machines in RTDS

## 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](http://www.rtds.com)

Contact us: [dehkordi@rtds.com](mailto:dehkordi@rtds.com)

