NovaCor™

A revolution in real time.

PHIL Developments to Improve Stability Margins

RTDS Technologies

Presentation Outline

Review of PHIL

Open Loop vs Closed Loop

Key Factors for PHIL Simulation

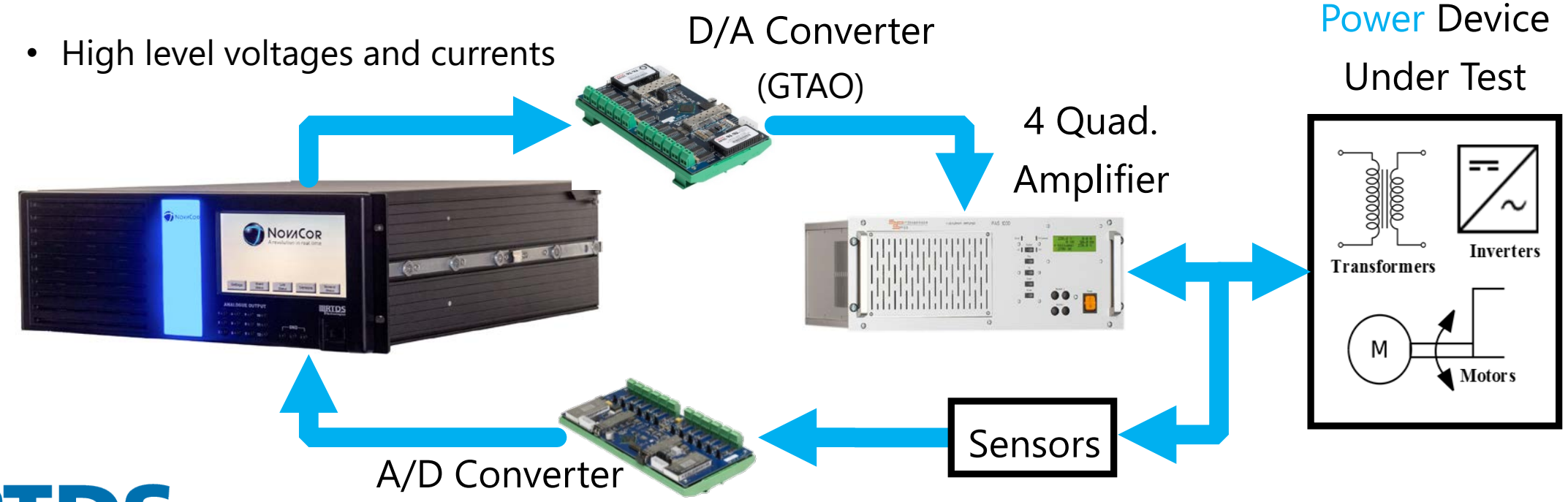
Recent Developments

Recent PHIL Work (Aurora Interface)

Future PHIL Work

Power Hardware In Loop (PHIL)

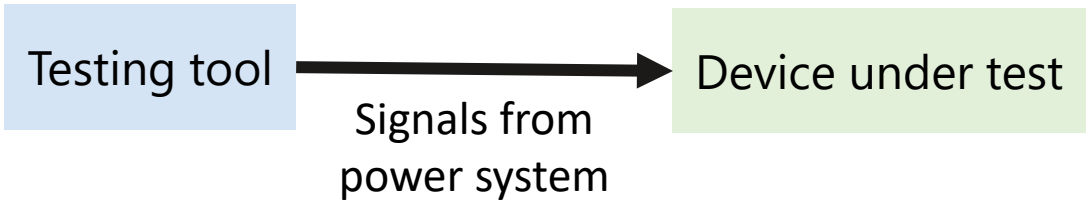
- In PHIL,
  - A portion of the power system is modeled in RTDS
  - Power exchange via 4 quadrant amplifier
  - High level voltages and currents



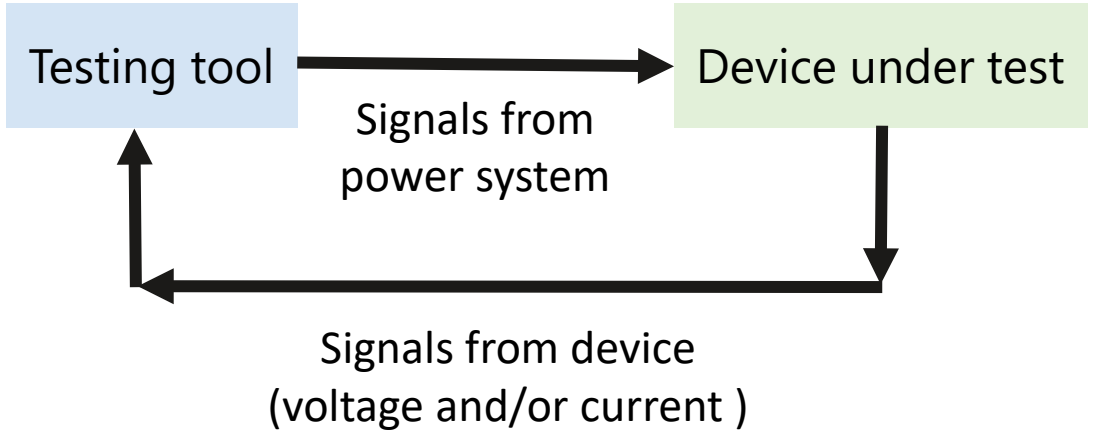
Open Loop vs Closed Loop PHIL

- Some applications might consider open loop as PHIL
- Challenges comes from closing the loop for kW to MW range
- All further discussions are referring to **Closed Loop** PHIL

Open Loop

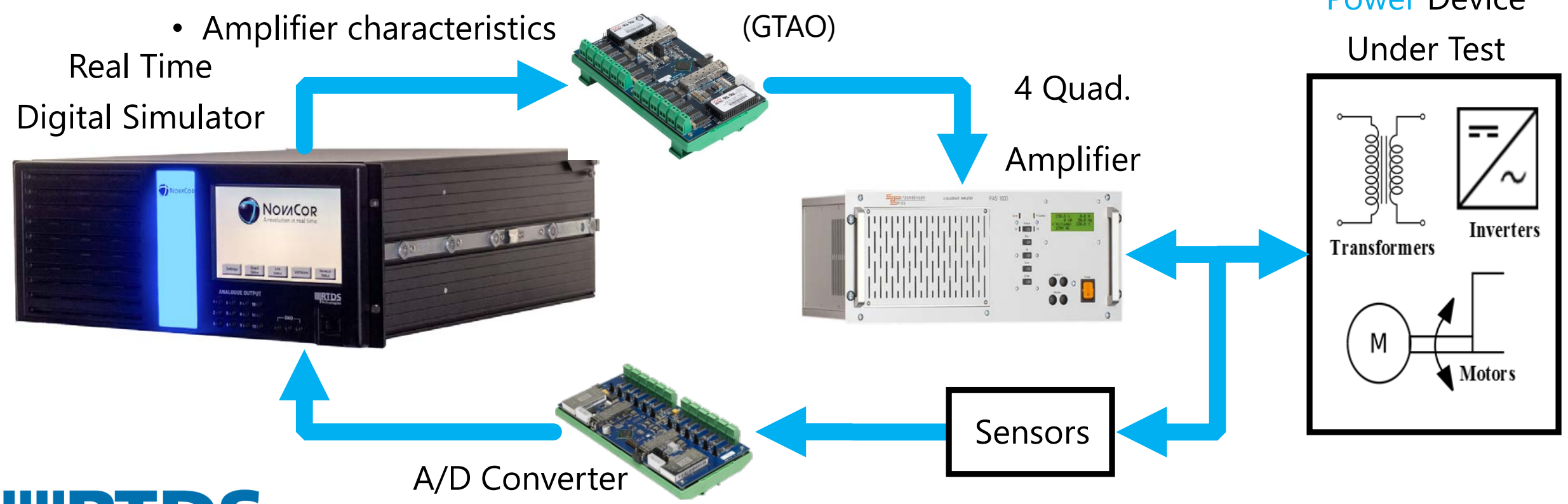


Closed Loop



Key Factors for PHIL Simulation

- Delays in the PHIL interface affect simulation accuracy and stability
- Size of simulation time step
- Amplifier characteristics



Recent Developments

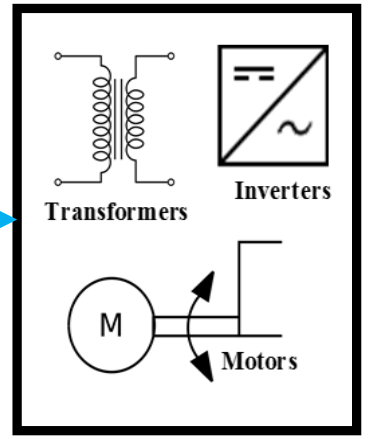
- Aurora Interface
  - Digital link between RTDS™ and Spitzenberger & Spies Amplifiers
  - Reduced loop delay & noise
  - Improved stability and accuracy

Real Time Digital Simulator

Aurora Interface

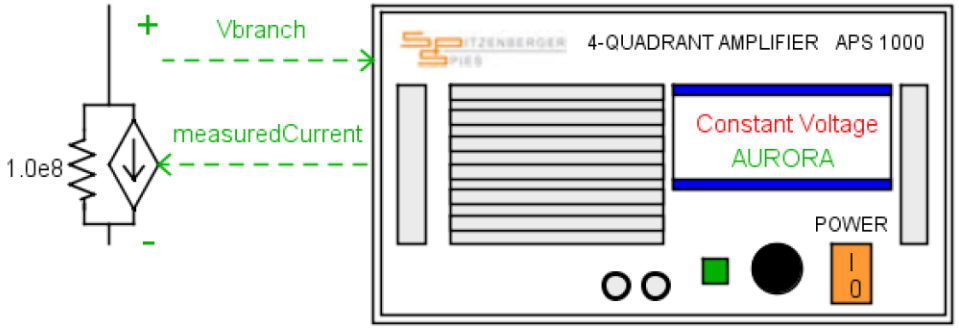
4 Quad. Amplifier

Power Device Under Test



Recent Developments

- SPS Aurora Component
  - Aurora link and voltage/current source embedded into a single component
  - Positioning of voltage/current interfacing sources can be reversed
  - Optimized timing for data exchanges to further reduce loop delay
  - Automatic or user defined scaling factors for over 12 SPS amplifier models
  - User controlled feedback switched for open/closed loop operation
  - Embedded CRC32 checksum for error detection during data exchanges

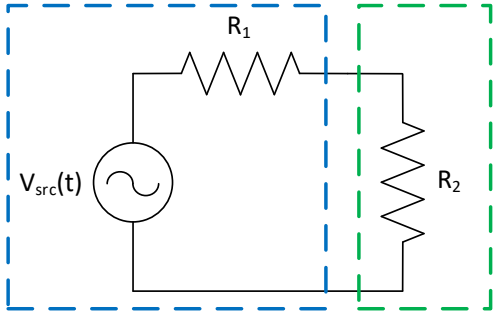


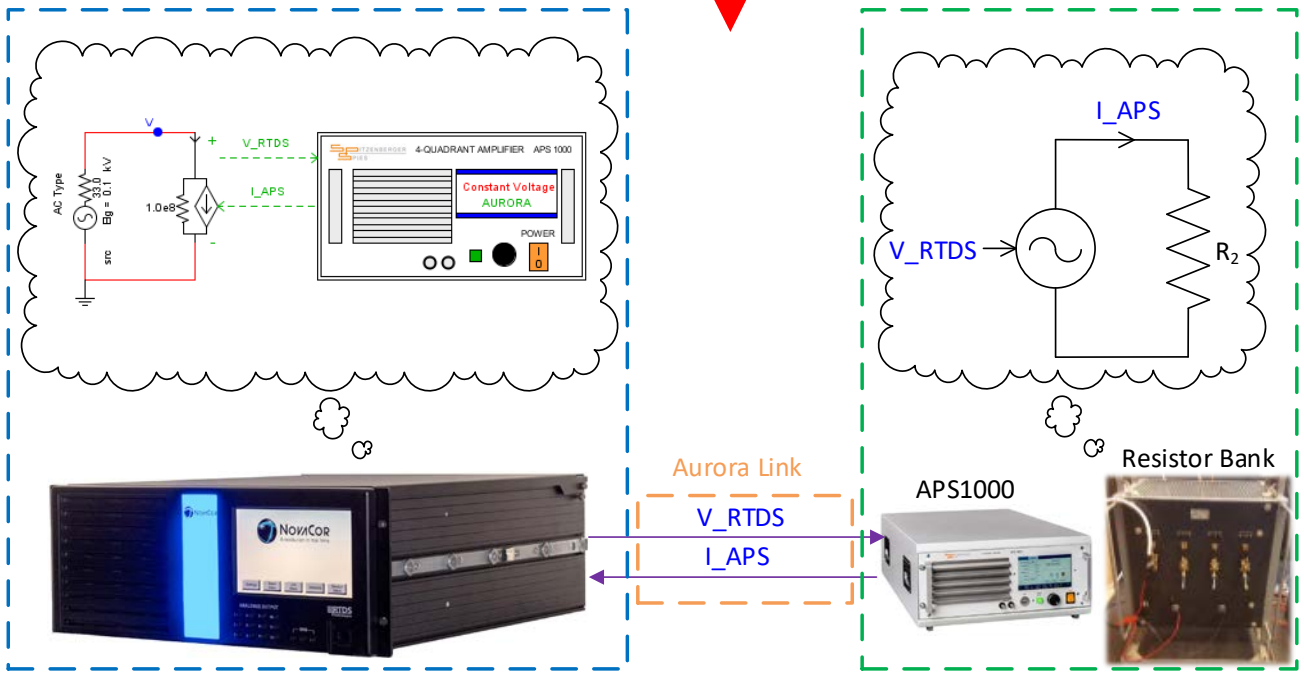
NovaCor™ Real Time Digital Simulator

Aurora Interface

Recent Developments

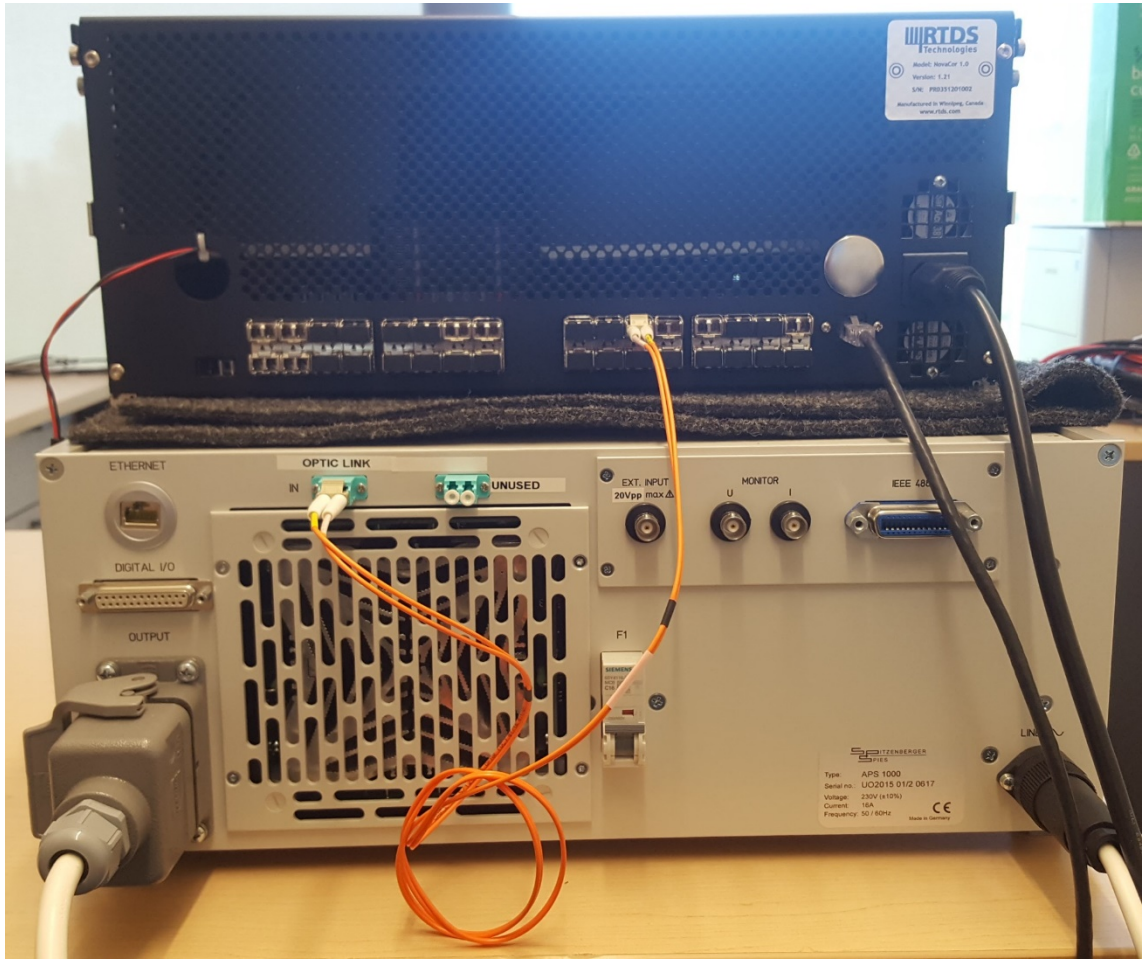
- Example: Voltage Divider with Aurora Interface
- Voltage source and source resistor on simulation side of PHIL interface
- Load resistor on amplifier side of interface
- From the perspective of the RTDS, voltage out, current in
- User configurable measurements delay and filter within SPS amplifier





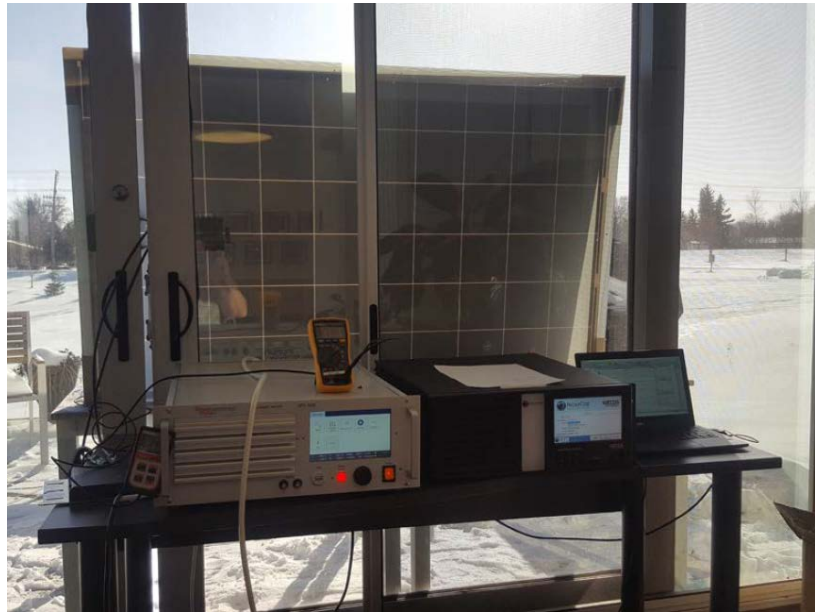
Recent Developments

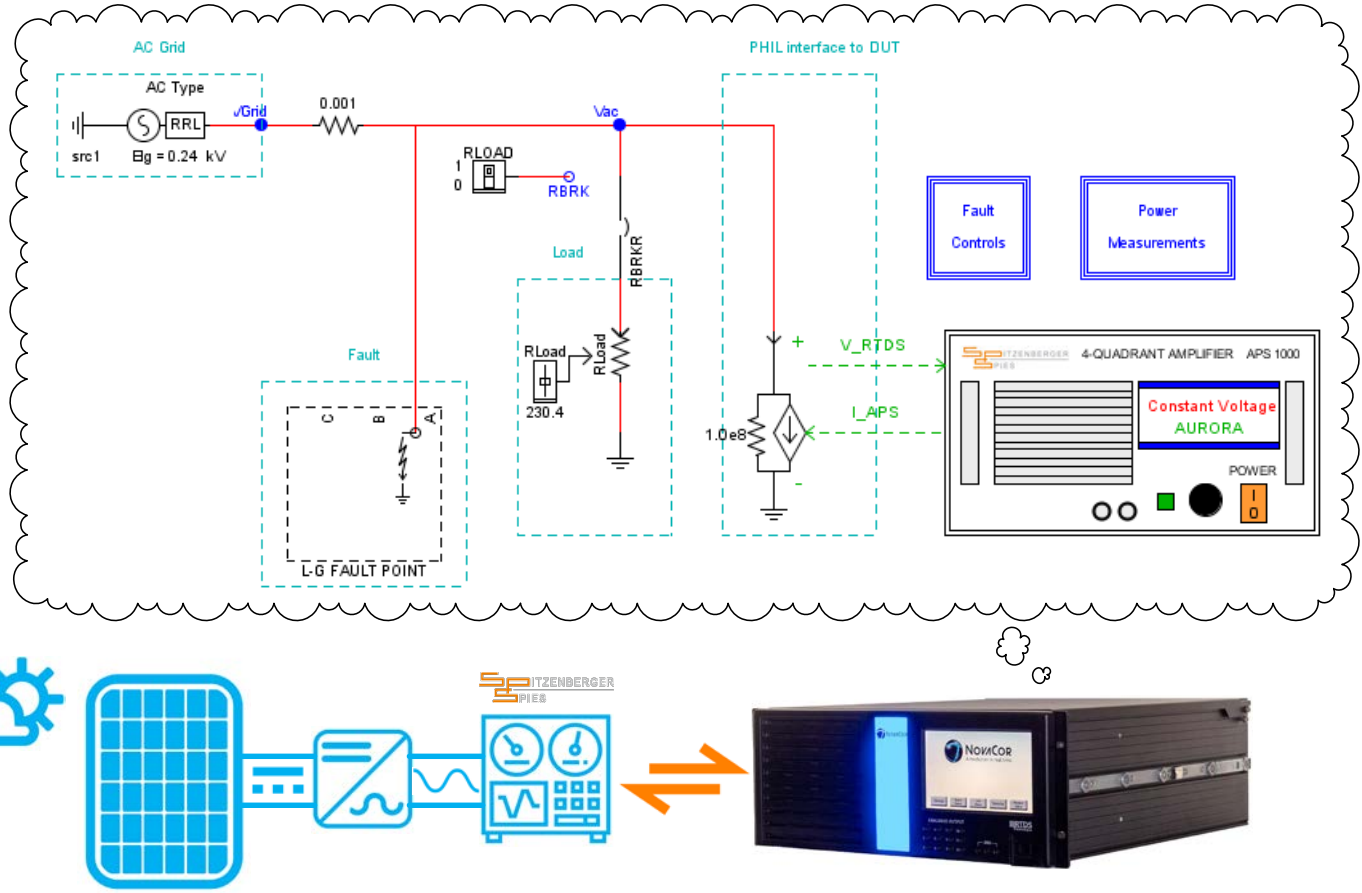
- Example: Voltage Divider with Aurora Interface
- Hardware Connections for Aurora Interface
- Requires a licensed Aurora Port on either PB5 or NovaCor based RTDS™
- Eliminates use of Analog Output/Input cards in PHIL interface
- Simplifies wiring and eliminates possibility of user error when wiring



Recent Developments

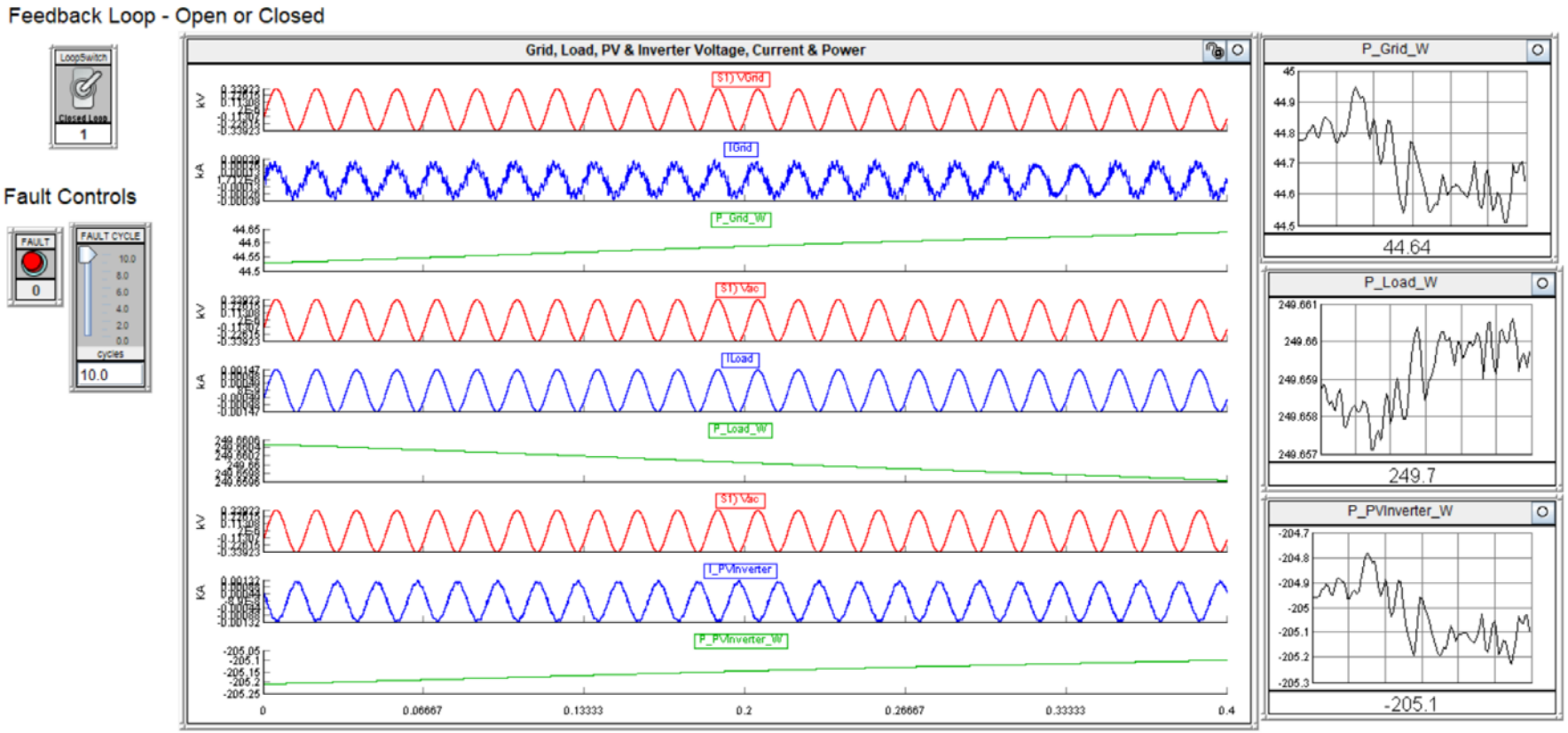
- Example: PV Panel & Micro Inverter
- 255W PV Panel
- 225W Microinverter





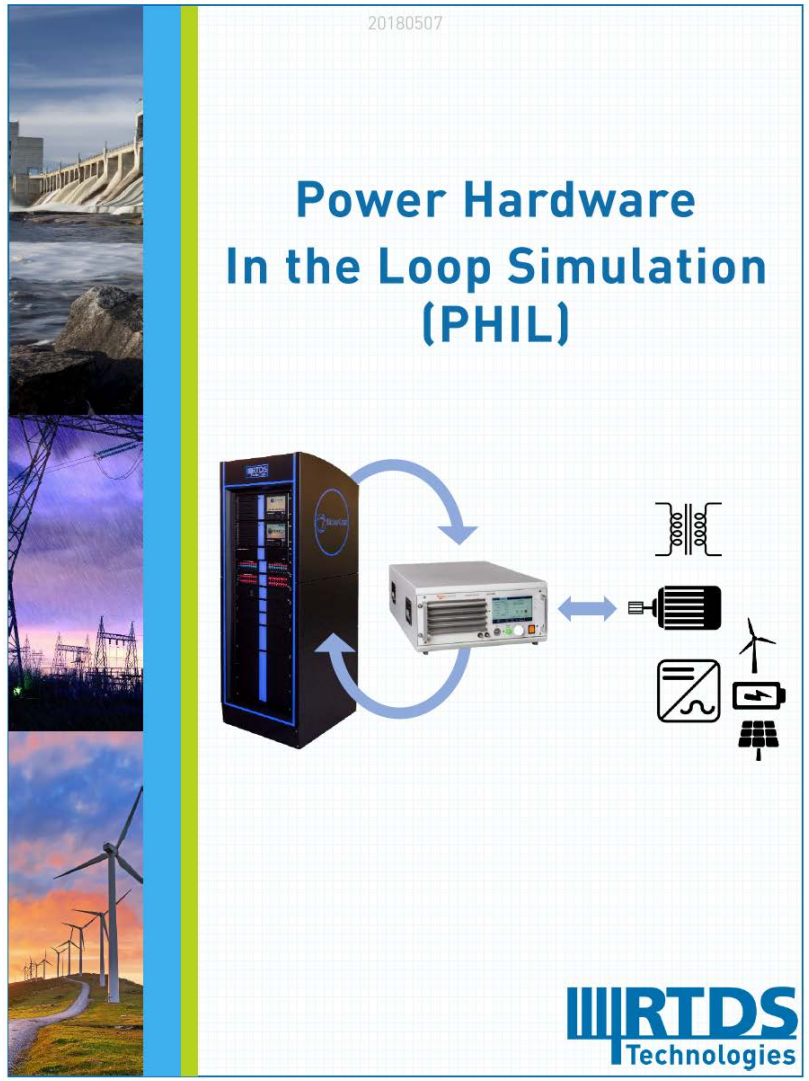
Recent Developments

- Example: PV Panel & Micro Inverter
- 250W Load
- 45W from simulated AC grid
- 205W from PHIL PV panel & microinverter



Conclusions

- Aurora interface offers improved accuracy and stability due to newly developed component models
- PHIL Report documenting our experiences
  - Freely Available on our website (https://www.rtds.com/wp-content/uploads/2015/12/RTDS_PHIL_Report-2.pdf)
  - Discusses key factors for PHIL simulation
  - Interface Algorithms
  - 4 Quadrant Amplifiers
  - Characterizing PHIL Interface
  - Stability and Accuracy of PHIL Interface
  - PHIL Applications (e.g. PV Panel & Microinverter)



Questions?