# Data Center Webinar Week
# Episode #1

## Fundamentals of Modelling and Testing Data Centers with the RTDS Simulator

RTDS Technologies

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# Also this week @ 10 AM CT:

## TUESDAY

**Data Center Power Management: In & Out**
**with Schweitzer Engineering Laboratories**

*Register here*

## WEDNESDAY

**Practical Insights and Study of 500MW+ Datacenter Co-located with Synchronous Generation**
**with Elevate Energy Consulting**

## THURSDAY

**Importance of Real-time Simulation in Enabling Seamless Interconnection and Operation of Large Loads including Data Centers**
**with EdgeTunePower and DEMA Energy**

# About RTDS Technologies

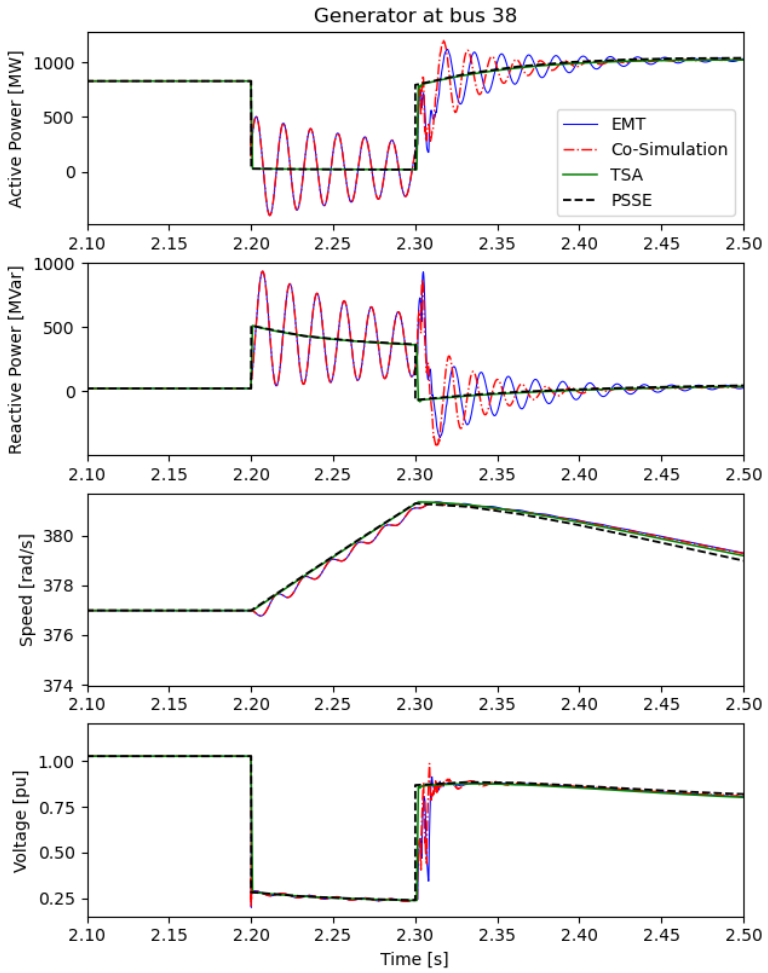

- Headquarters in Winnipeg, Canada
- The RTDS Simulator is the industry standard for real-time simulation and hardware-in-the-loop testing, used by utilities, manufacturers, research and educational institutions, and consultants worldwide
- De-risking technologies for the future power system

# Hardware-in-the-loop applications

- Renewables/DER interconnection studies
- Power plant controller testing
- Protection testing, including IEC 61850
- HVDC & FACTS testing
- Data center protection & control
- Distribution automation
- Microgrid control testing
- Power electronics
- Wide area scheme testing
- Cyber security


- Learn more at www.rtds.com or the large library of videos on the RTDS Technologies YouTube channel

# EMT power system simulation




- Greater depth of analysis than traditional phasor domain (RMS) representations
- EMT models are needed to represent inner loop controls of inverter-based resources/loads and related stability issues

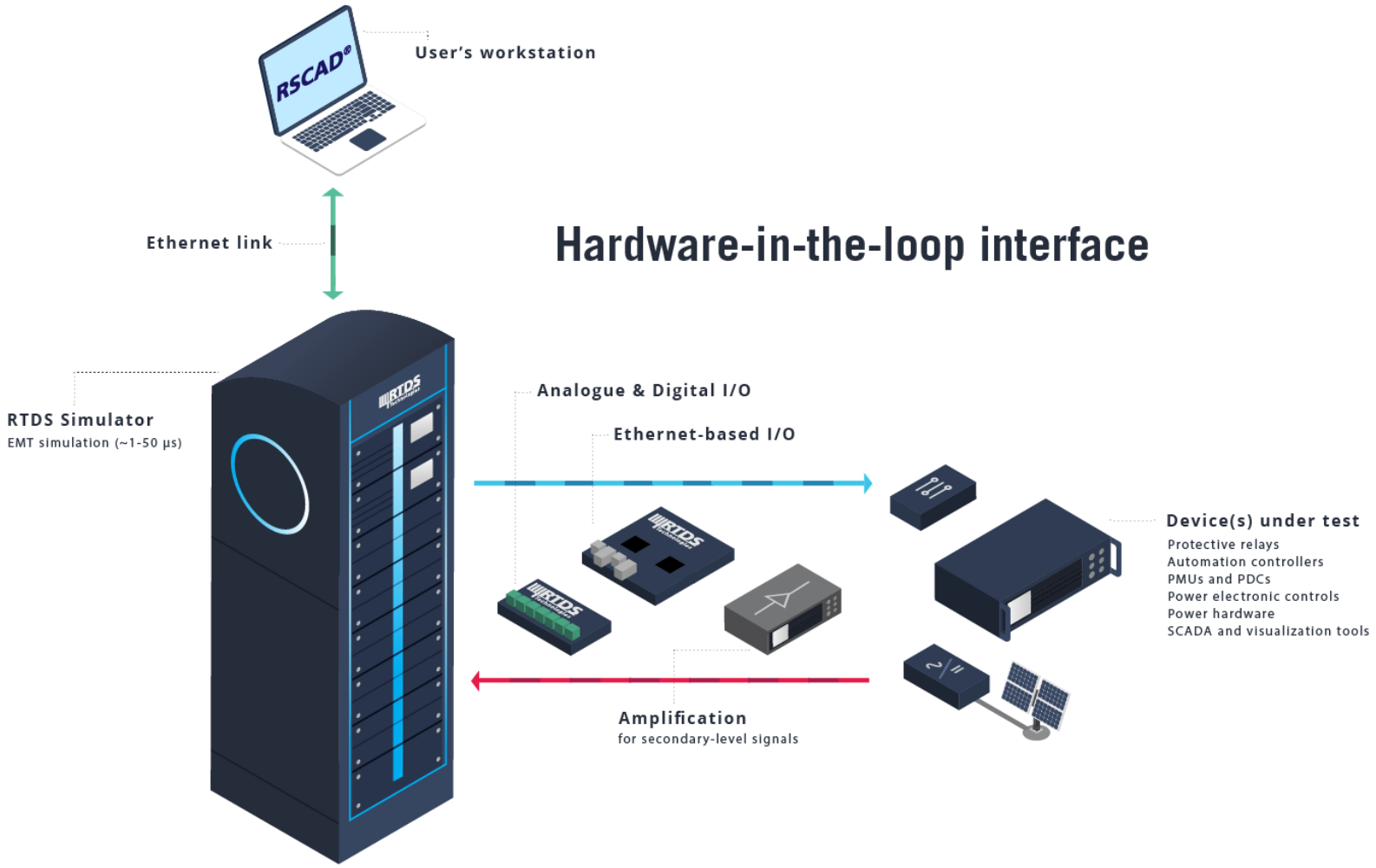
**Table 2.1: Solar PV Tripping and Modeling Capabilities and Practices**

| Cause of Tripping | Can Be Accurately Modeled in Positive Sequence Simulations? | Can Be Accurately Modeled in EMT Simulations? |
|---|---|---|
| Erroneous frequency calculation | No | Yes |
| Instantaneous* ac overvoltage | No | Yes |
| PLL loss of synchronism | No | Yes |
| Phase jump tripping | Yes | Yes |
| DC reverse current | No | Yes |
| DC low voltage | No | Yes |
| AC overcurrent | No | Yes |
| Instantaneous* ac overvoltage—feeder protection | No | Yes |
| Measured underfrequency—feeder protection | No | No** |

* Sub-cycle ** Due to very limited protective relay models in EMT today

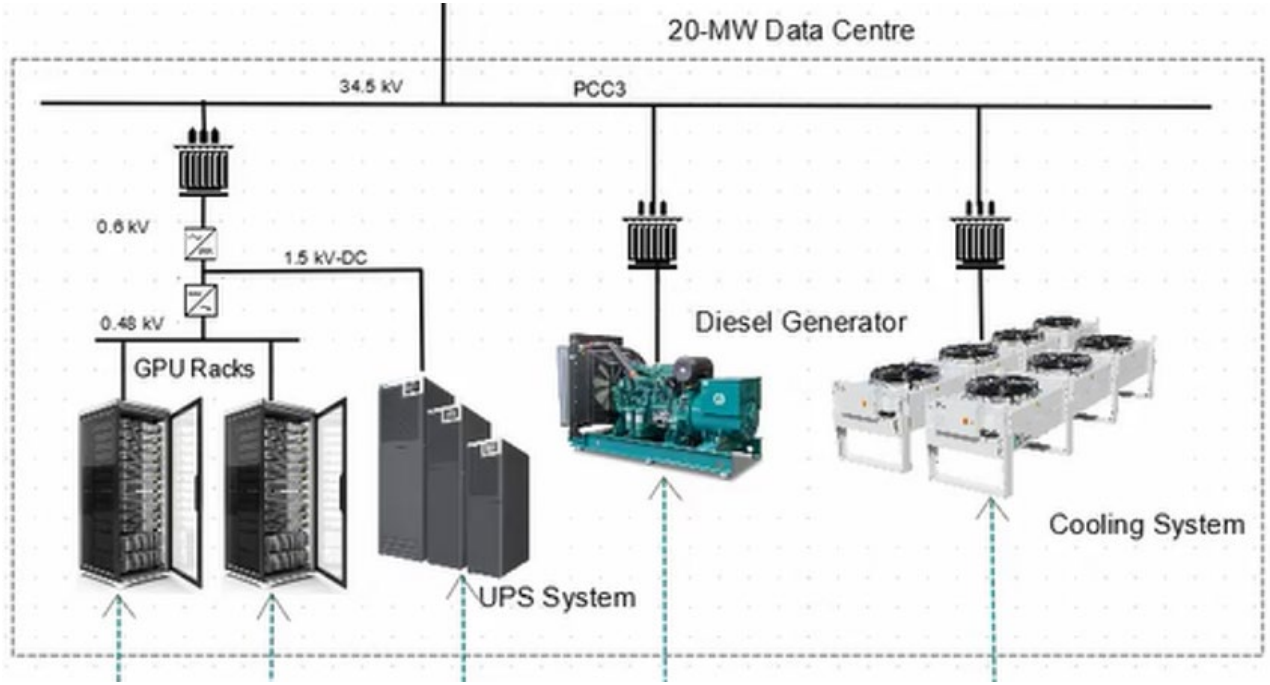
# HIL testing with a real-time simulator

- **True closed-loop testing** is only possible with a real time simulator
  - Test multiple devices (and entire schemes) at once
  - Much more detailed system representation than open-loop test systems provide (e.g. modelling power electronics)
  - Provides unique insights on interactions & dependencies that traditional modelling/ testing may be blind to



# De-risking data centers

- Real-time simulation and HIL testing supports the design and validation of data center electrical architecture – protection, inverter controls, EMS/PMS, and more
- Reliability and resilience of data center protection and control schemes can be demonstrated to stakeholders
- Improves the speed and cost of data center deployment
- RSCAD FX library includes components for representing energy generation and storage, UPS, GPUs, cooing systems, and more



# Data center testing outcomes

- In applying the RTDS Simulator to data center projects, our users have identified several issues
  - Coordination errors in relaying schemes due to lack of communication between engineering teams working on different aspects of design
  - Insufficient protection selectivity (transformer energization, zone selection)
  - Discovery of incorrect settings
- Opportunity for operators to gain experience with the system in a controlled lab environment and provide feedback on functionality

# Thank you!

**Contact me:**
**kati.sidwall@ametek.com**

# Data Center Modelling

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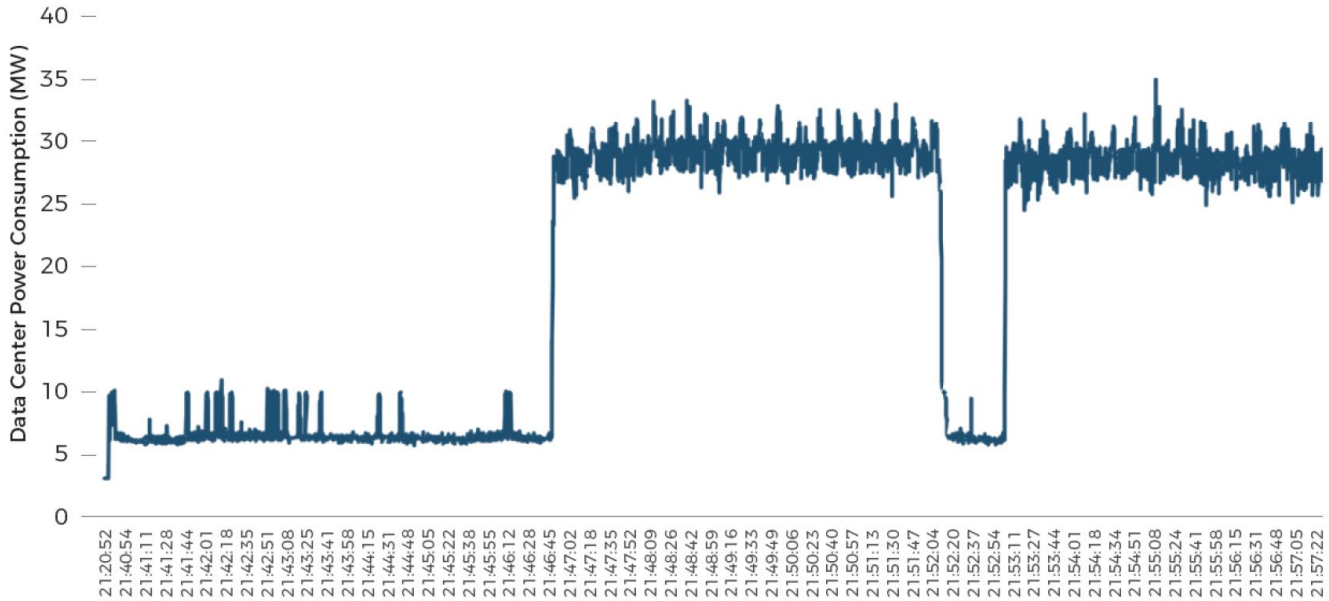
# Introduction

- Data center facilities are critical loads
- New large-scale AI data center loads places a lot of risk on the existing grids.
- Utilities need to better understand the impact of large data center loads to the existing grid
- Performing accurate EMT studies for dynamic simulation studies is critical
- HIL provides ability to de-risk physical control and protection system
- Industry needs improvements in modelling and study practice
- Important to develop dynamic data center load model for simulation studies
    - Minimal data center models and literature available
    - What does the data center architecture look like?
    - It is evolving

# AI Data Center characteristic

- Power electronic loads
- Load fluctuation
- Fast transients and ramp rates
- Uptime is very important, ~99.9995%
- Sensitive control and protection
- Data center loads will disconnect due to disturbance on the grid.
- Risk of frequency and voltage swings due to load drop
- Concerns for regions which include data center clusters.




Source: ETP

# Data center components

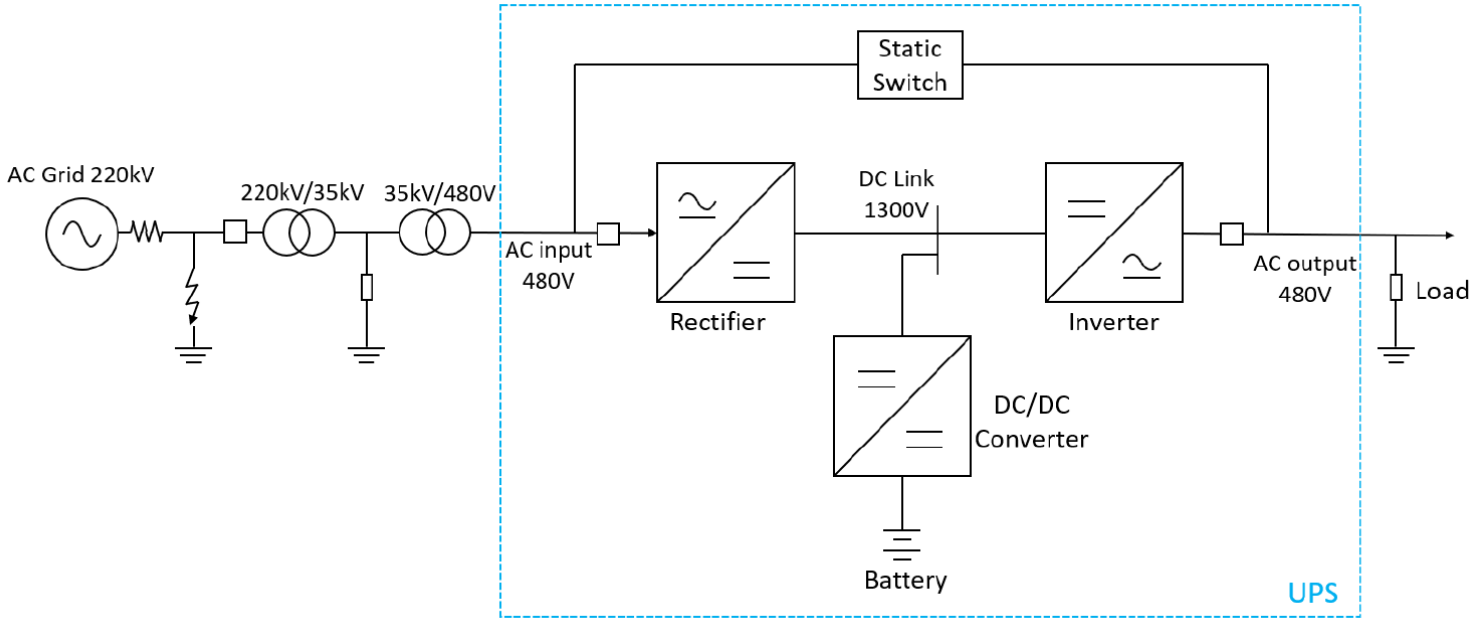
- IT equipment → 40-50% of energy consumption
  - Servers
  - Storage systems
  - Network infrastructure
  - ..
- Cooling system→ 30-40% of energy consumption
  - Chillers
  - Control Room Air handler (CRAH)
  - …
- Auxiliary Component → 10-30 % of energy consumption
  - UPS
  - Lighting
  - Security system
  - …

Ref:TRG

Source [EPRI]

# UPS

- Decouples AC grid and Load
- Provides conditioned waveform to Load and emergency power to the load
- Critical part of a data center to ensure clean and reliable power to AI load
- Can abruptly disconnect DC load from the grid and provide temporary backup battery power
  - Potential voltage and frequency swings to the grid (e.g. clusters)
- Higher rated centralized UPS configuration for future large loads.
- **Derisking protection and control system is critical**




Double conversion UPS

# UPS Operation modes

Dynamic response will be impacted by mode of operation

## Double Conversion (Online) mode

- UPS switch path supports the load with conditioned power. Battery can be charged. Rectifier regulates DC link

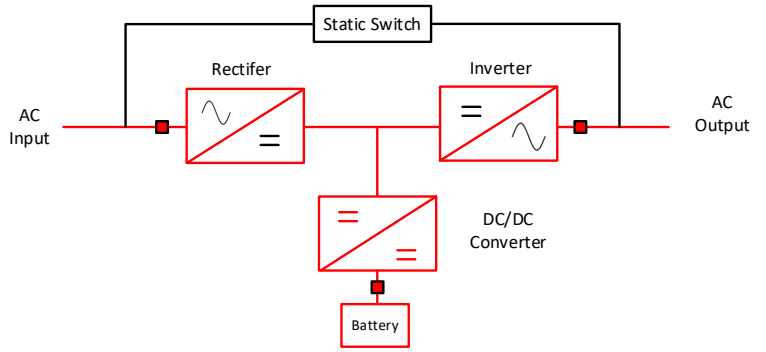
## ECO (Bypass) mode

- Static switch is “closed” and load is supplied directly from Input (grid). Can reduce energy loss. Battery can be charged

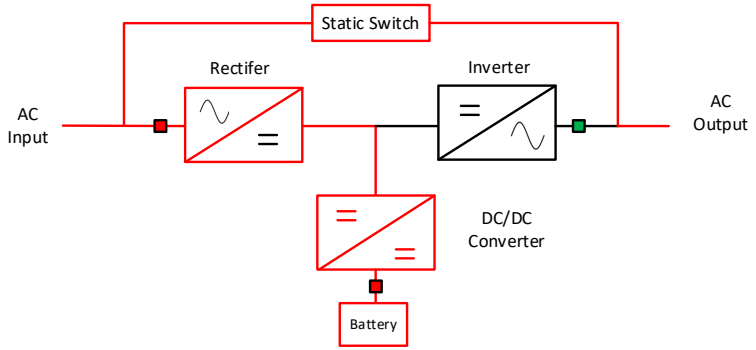
## Battery mode

- UPS disconnects (e.g. supply failure) from input and transfer to battery to supply load with conditioned power. DC/DC converter regulates DC link

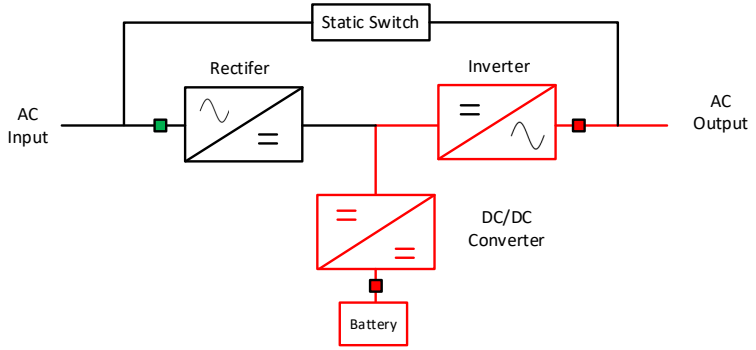
**Double Conversion (Online)**




**ECO (Bypass)**




**Battery Mode**



# Cooling system

## Do we need to represent the cooling system?

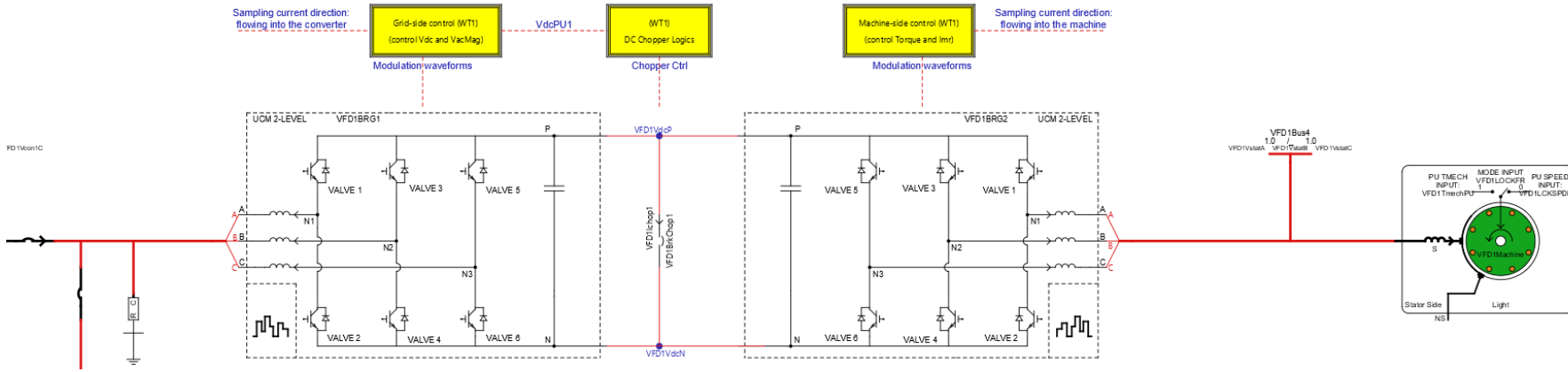
Cooling system→ 30-40% of energy consumption

## Chiller

- Remove heat from a liquid (water) that is circulated through facility.
- Motor Load(s)

## Control Room Air Handler (CRAH)

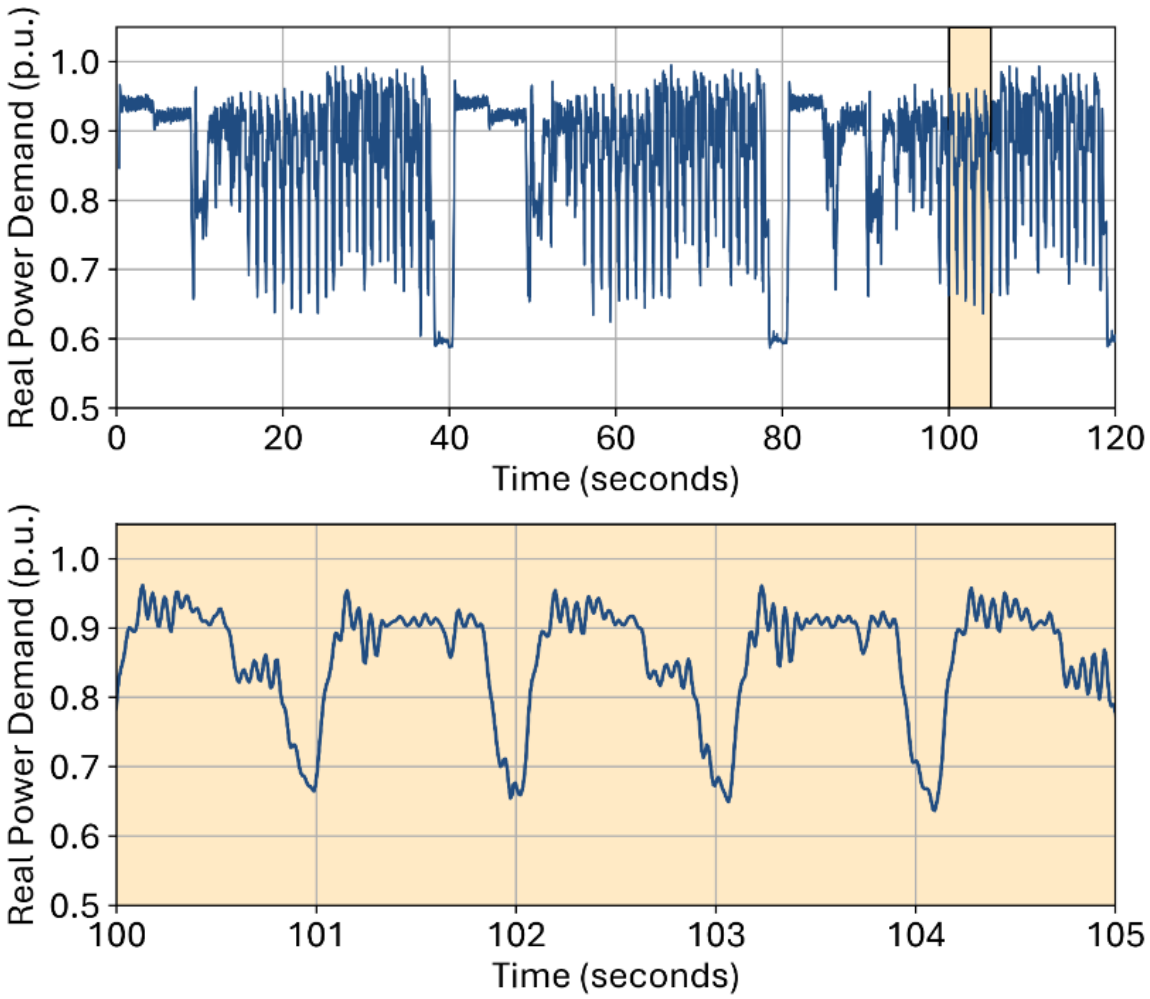
- Maintain temperature and humidity. Fans to blow air over cooling coils field with chilled water
- Variable speed systems to maintain temperature, more efficient
- Back to back converter topology




Variable Frequency Drive

# AI Load

- New generative AI load
- Variable load profile, fast transients and ramp rates
- Can lead to voltage fluctuation
- Forced oscillation below system frequencies
- Managing hundreds of MWs of load in fraction of a second is a major challenge.
- Historic generation cannot support such swift changes, ramp rates are too slow.
- IBR generation such as Wind and PV are intermittent



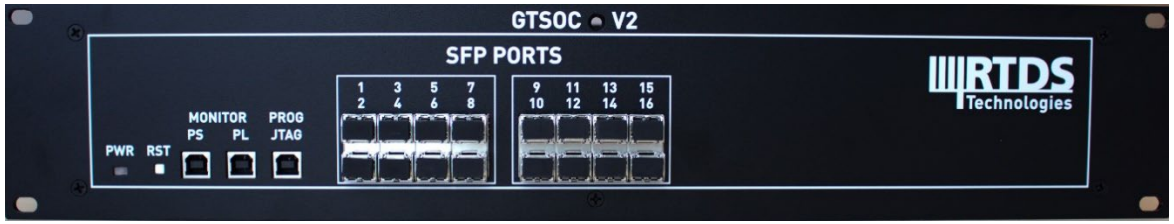

Ref: NERC whitepaper Characteristics and Risk of emerging Large loads

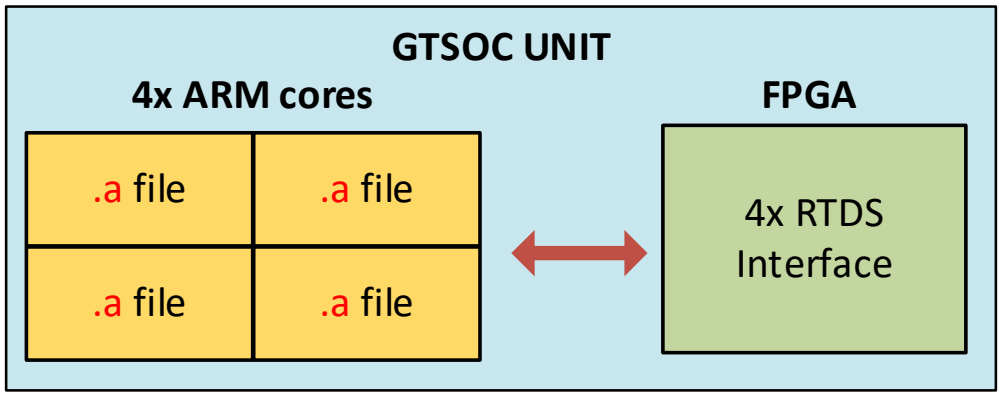
# Energy Storage

- Data Center loads are not currently required to support the grid during faults
- Data Center loads can also contribute to system instability, especially in high IBR penetration areas.
- Co-located energy storage  can provide grid support
  - Voltage and frequency support
  - Islanding support to data center (if needed)
  - Protect grid against oscillation and load surges from AI load
- BESS and/or E-STATCOM are possible solutions.
- Access to vendor models is important for accurate results.

# Software in the loop (SIL) black box models

- Onsite IBR generation and energy storage solution to support the energy needs of the data center.
- Vendor specific control models are critical to the accuracy of IBR EMT models
- HIL may not be available, SIL models is an option.




Fibre Cables

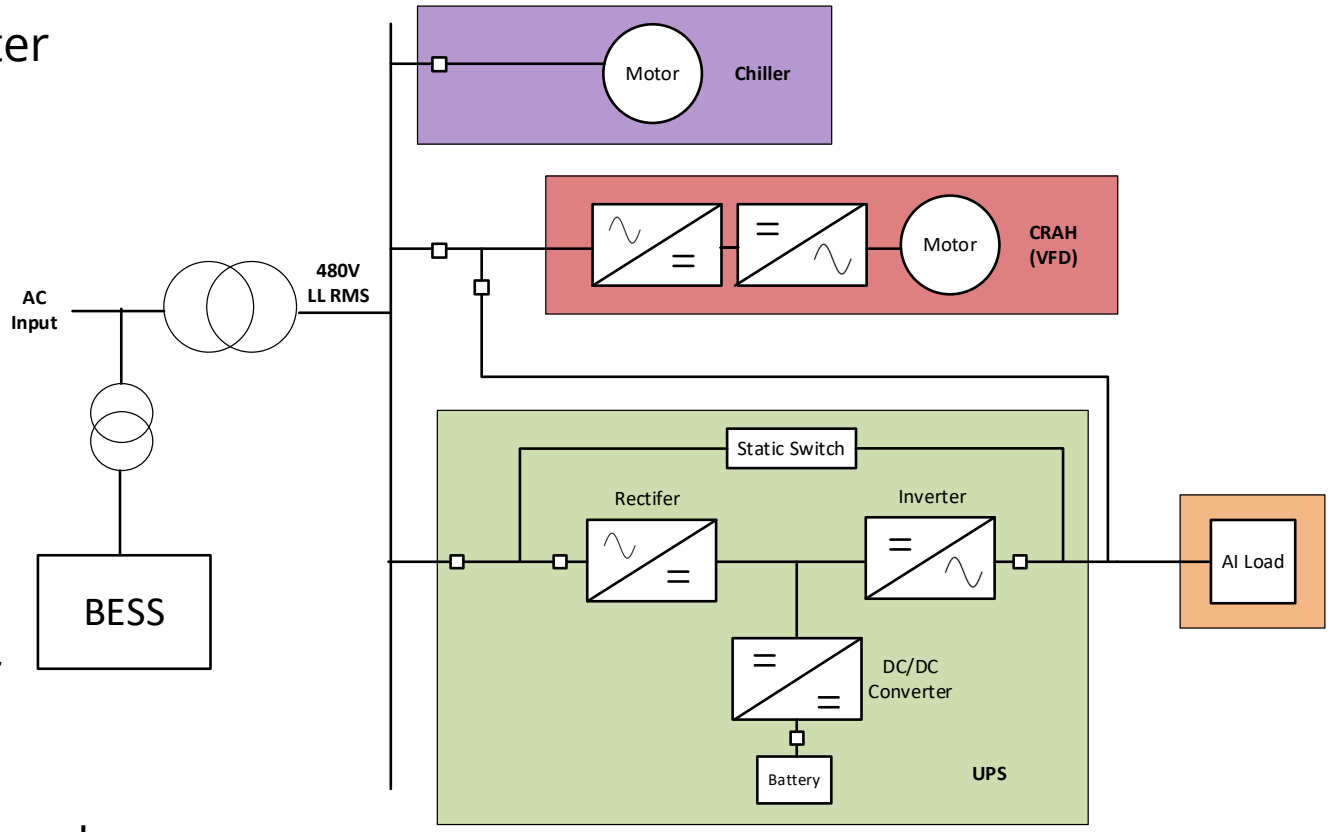
NovaCor Chassis

# Data Center Modelling

- To receive a vendor specific data center model is challenging
- Different parts of the of the load are from different vendors
- Different design, no standard models
- Generic models can be suitable for certain applications.

# Data Center Model

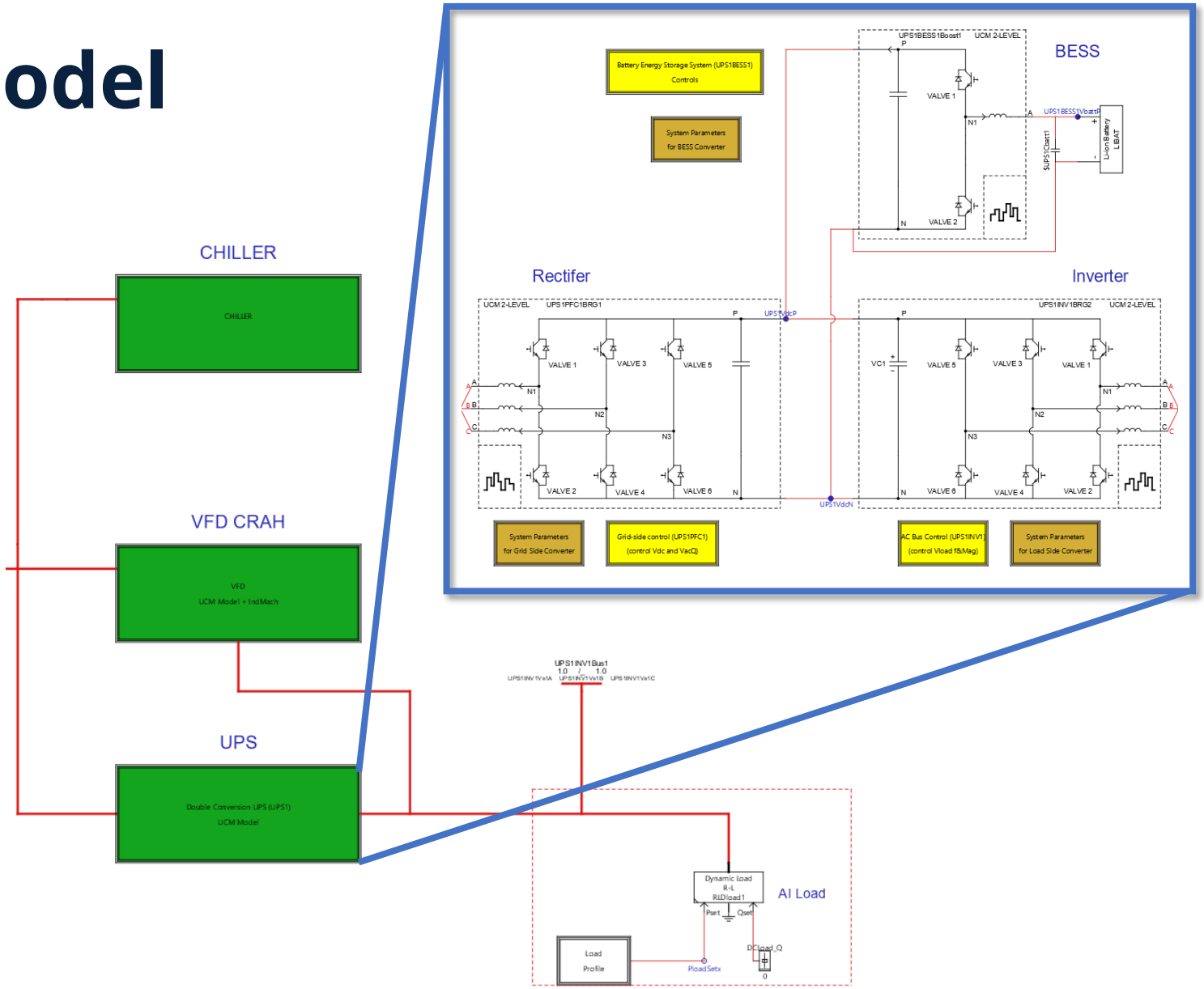
- RTDS have been actively developing a Data Center example model
- Considering the following
  - Chiller
  - VFD CRAH
  - UPS
  - AI load
  - Co-located BESS
- Use aggregation to represent larger Data center load
- Continue to develop/update model as guidance and architecture evolves




J. Sun, S. Wang, J. Wang and L. M. Tolbert, "Dynamic Model and Converter-Based Emulator of a Data Center Power Distribution System," in *IEEE Transactions on Power Electronics*, vol. 37, no. 7, pp. 8420-8432, July 2022

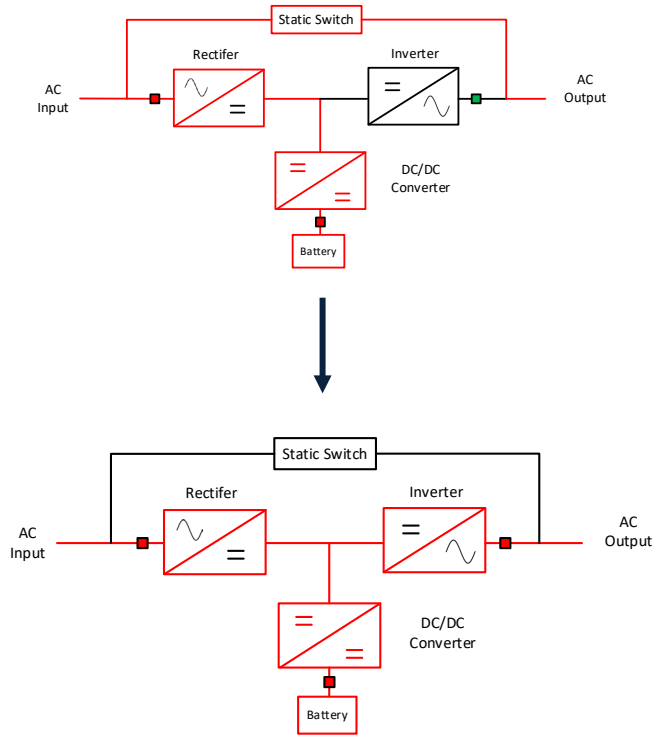
# RTDS Data Center Model

- RSCAD FX library includes components for representing energy generation and storage, UPS, cooling systems, dynamic loads and more
- Details generic controls of UPS, VFD and co-located GFM BESS
- Supports the design and validation of data center electrical architecture – protection, inverter controls, EMS/PMS, and more



# Simulation Results

- **Testing functionality of the UPS control/protection**



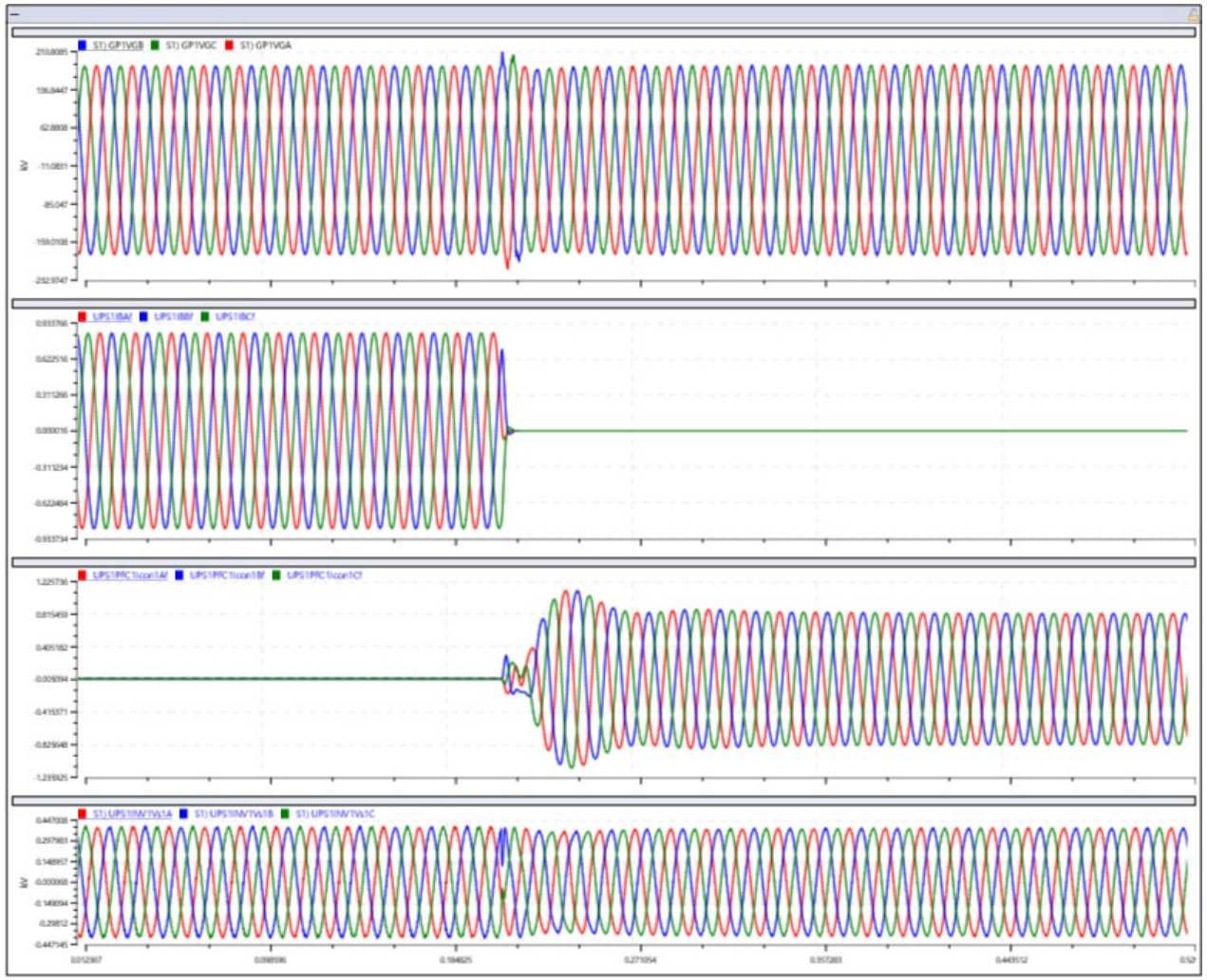

Operation of UPS ， Bypass-> online mode

Grid Voltage (POI)

Bypass Current

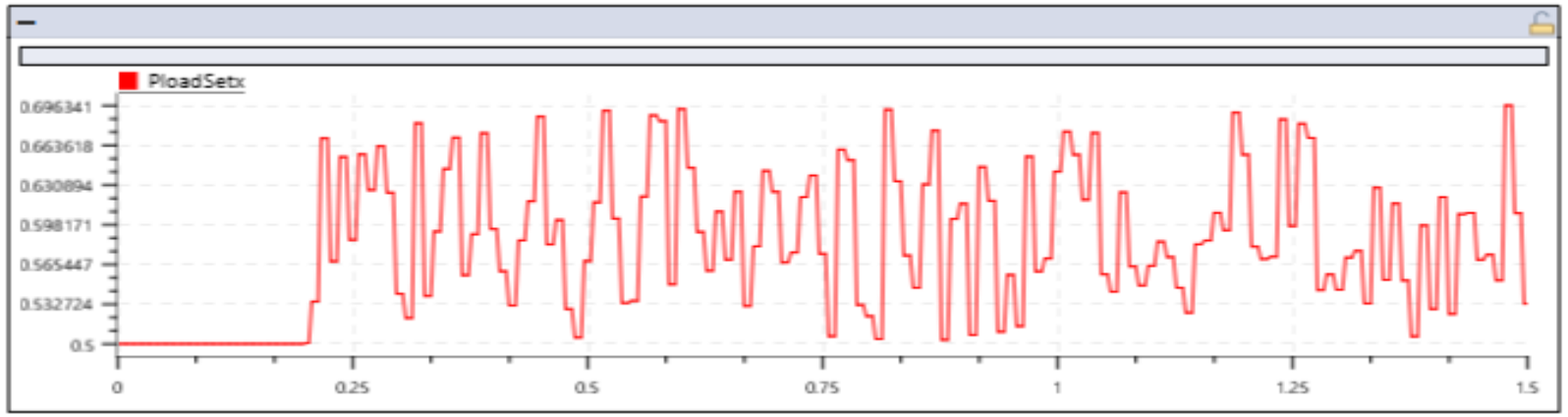
Online Current

Load Voltage

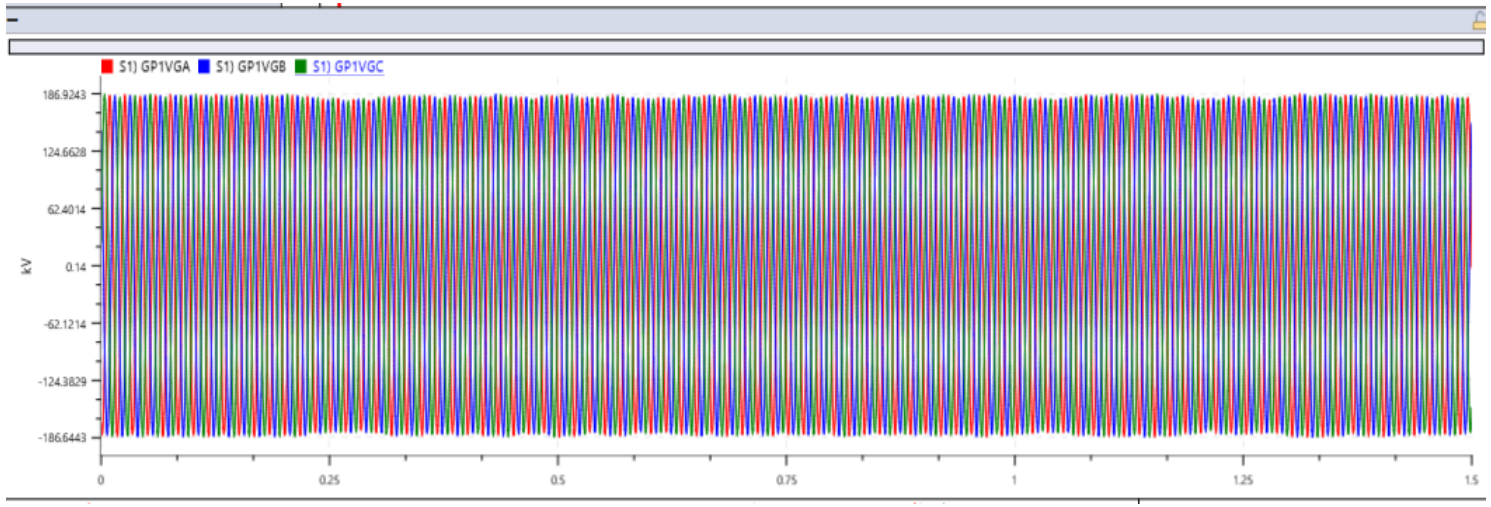


# Simulation Results

- Create custom load profile
- Sub-synchronous oscillations observed from fluctuating load
- If real load profile data is available, can be played back in the simulation



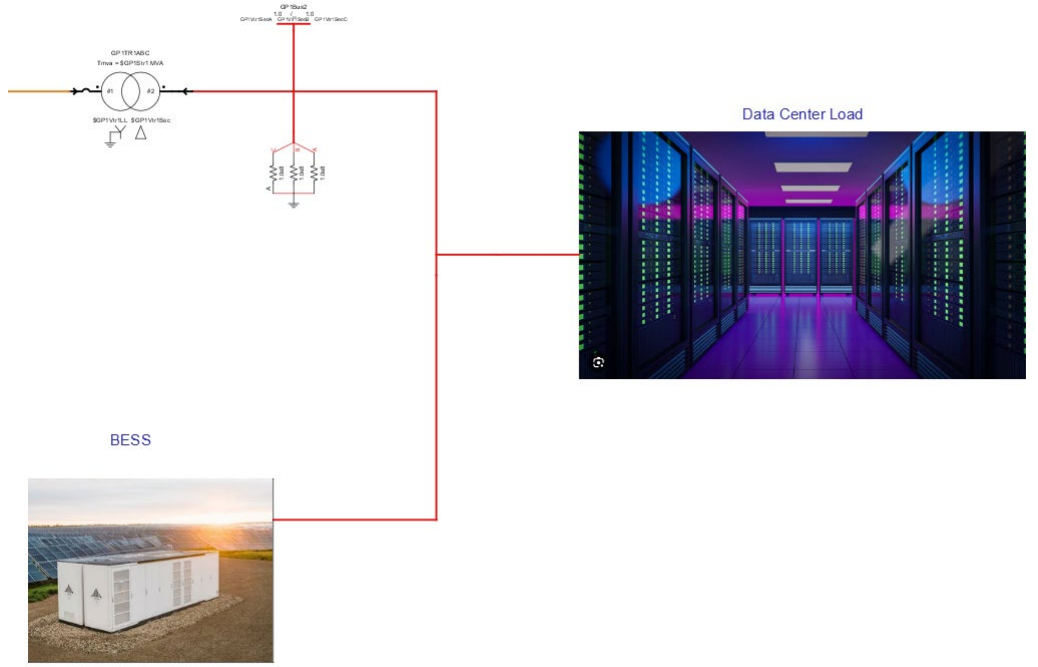

Load Profile

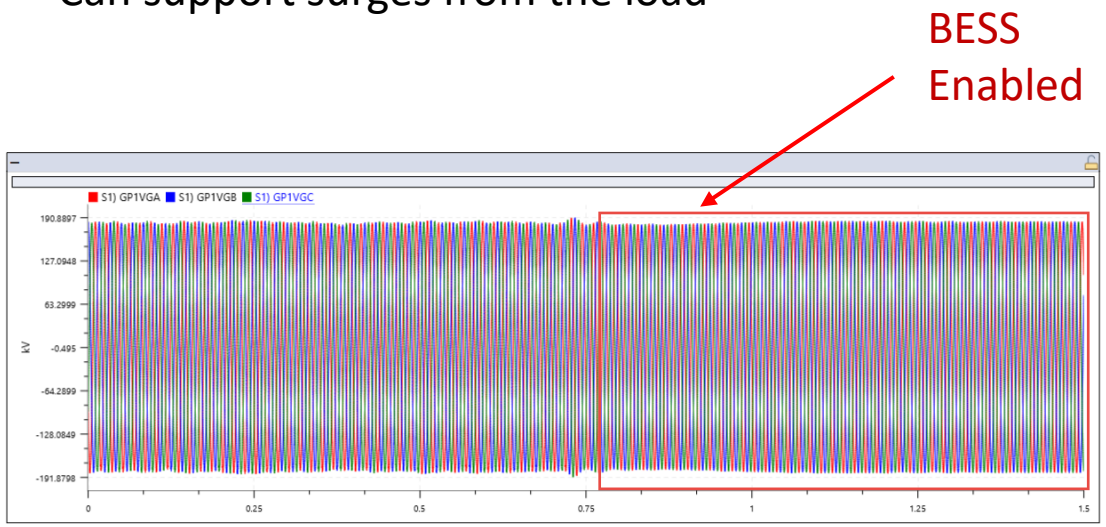



Grid Voltage (POI)

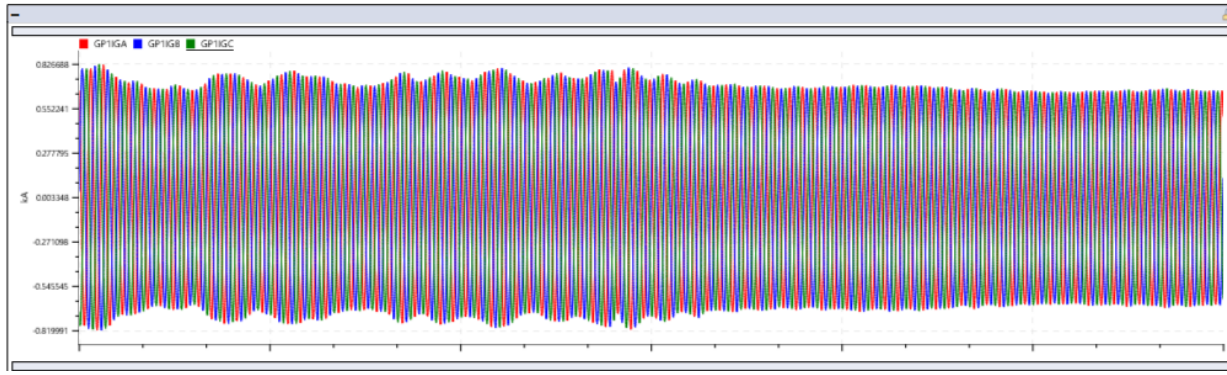
# Simulation Results

- Simulating the impact of adding grid forming BESS to provide V/F support
- Can inject/absorbed active and reactive power
- Reduces oscillation seen from the grid
- Can support surges from the load




Grid Voltage (POI)




Current (POI)

# Demonstration

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# Key Takeaways

- Modern and future Data Centers have:
  - Never-before-seen power demand and density per site
  - Dynamic Load profile
  - Unprecedented performance requirements, 99.995% availability
- EMT simulation is critical to model the complexity in the load facility and capturing the fast transients
- Real time simulation can de-risk the physical control and protection to validate performance and ensure uptime requirements are met.
- Developing data center example model(s)
  - Generic models of UPS, VFDs, co-located BESS
- DC Load architecture are evolving

# THANK YOU!

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