CORPORATE UPDATE & INDUSTRY TRENDS

PAUL FORSYTH & KATI SIDWALL

RTDS TECHNOLOGIES INC.

RTDS TECHNOLOGIES

- Approximately 80 staff in Winnipeg office
- Added 13,500 square feet (1255 m^2) to our facility for a total of 37,500 square feet (3485 m^2)
- Faired well during COVID and market has been very strong ever since
- Revenue for 2022 was over 50M USD and the outlook for 2023 is excellent

RTDS MARKET

- Remain strong in traditional market sectors
- New and emerging markets
  - Energy companies moving to green energy
  - Server farm companies decarbonizing energy supply
- Large-scale simulators
  - In 2023, 10 projects over 1M USD, one over 9M USD

AMETEK INTEGRATION

- Very smooth process, particularly considering the change in corporate culture
- New reporting requirements as part of a public company
- New IT policies and requirements
- Looking to leverage global presence
  - Improve RMA process
  - Local support
- Overall, it's business as usual!

AMETEK OVERVIEW

- Global manufacturer of high-tech industrial solutions
- Annual sales over **$6.0** billion with approximately **50%** of sales outside U.S.
- Diverse set of niche markets and applications served
- Distributed operating structure with **~19,500** colleagues worldwide
- Experienced management team with a proven track record of creating shareholder value by executing the AMETEK Growth Model
- Strong set of Core Values serve as the backbone of our long-term, sustainable growth

OUTLOOK MORE THAN BRIGHT

- Market for foreseeable future in excellent
- Driven by strong growth in traditional sectors, HVDC, FACTS, etc.
- New and emerging markets adding to opportunities
- Looking to develop new market verticals

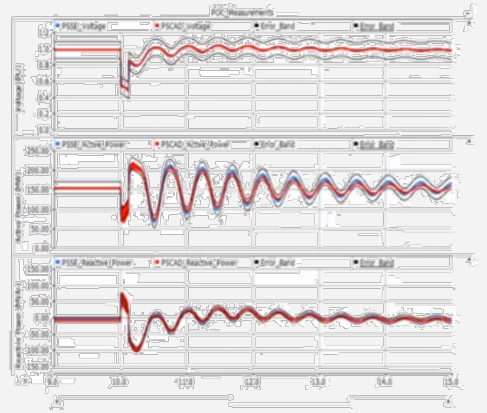
THE IMPACT OF INVERTER-BASED RESOURCES

- Inverter-based resources and their impact on the stability and dynamic behaviour of the grid are at the center of many conferences, working groups, utility activities, and research/consulting projects
- Significant portion of RTDS usage is related to de-risking or validating IBRs and their control and protection
- General issues are now well understood, but variation in manufacturer control approach means that risks of interaction/misoperation are project specific

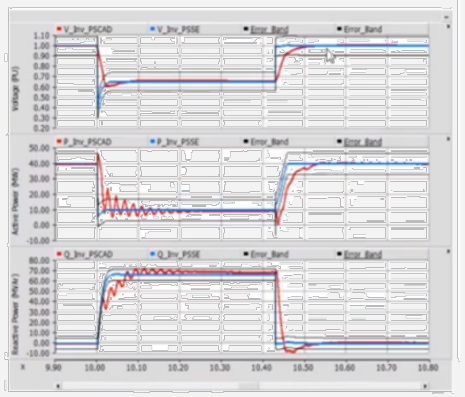
INDUSTRY SHIFT IN MODELLING APPROACH

- Traditional load flow / TSA models have major limitations when it comes to the modern IBR-based grid
  - RMS models cannot represent inner loop controls of IBRs; limitations in precisely assessing ride-through performance
  - Many system stability issues observed during high-penetration of IBRs are not easily detectible
  - Significant uptake of EMT simulation by utilities/SOs – “EMT simulations becoming standard practice” (NERC)

Synchronous generator fault ride through



Wind farm fault ride through



GROWING NETWORK SIZES & COMPLEXITY

- General movement toward EMT simulation and more information on its advantages means that users (especially utilities) are interested in simulating larger networks
- HIL may or may not be the goal in these situations; there is a focus on efficient large-scale EMT simulation
- Non-real time may be sufficient

NON-REAL-TIME ON NOVACOR 2.0

- Non-real-time mode allows for 10x more nodes and load units than real-time mode
- Effectively gives the user the real-time capabilities of an entire chassis on a single core in non-real-time
- Not the same as offline simulation

TSA MODULE

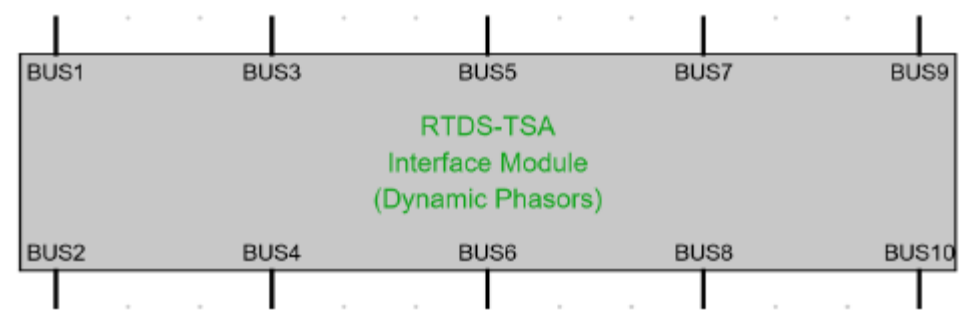
- Minimum requirements:
  NovaCor hardware, RSCAD FX 1.4

- TSA programs are used to determine the stability of a power system in phasor domain.
  - Simulate much larger networks than EMT, with much larger timestep

- Dedicated TSA core runs up to ~2000 buses
  - Interface TSA module with EMT simulation (co-simulation/ hybrid simulation)
  - Standalone TSA simulation also supported

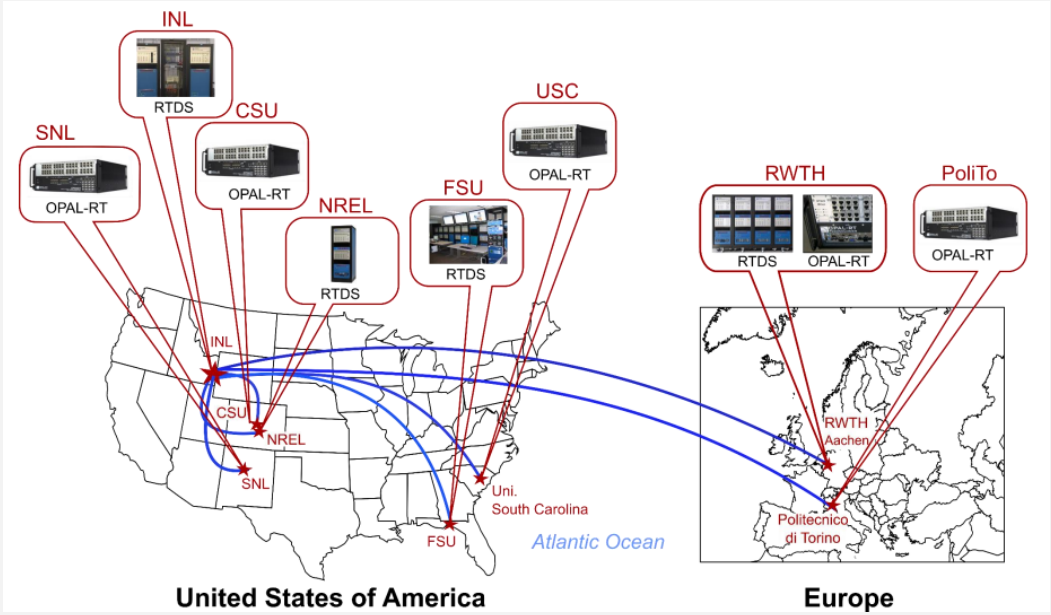
TSA MODULE

- PSS/E data files are required as input
- To interface the TSA module to an EMT model, an interface module based on Dynamic Phasors (DP) is available in the RSCAD library. A GUI named “RTDS-TSA Setup” is available to initialize the TSA in RTDS.



GEOGRAPHICALLY DISTRIBUTED SIMULATION

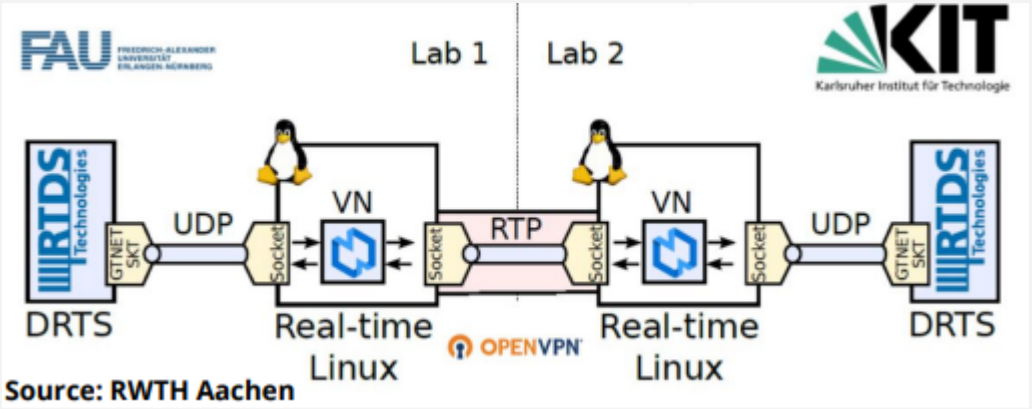
- Global interest in leveraging real-time simulation and HIL resources of other labs via geographically distributed simulation (i.e. remote interconnection of simulators)
- UDP port and GTNET-SKT support this type of connection
- May be EMT-EMT, EMT-RMS, or other



From NREL

GEOGRAPHICALLY DISTRIBUTED SIMULATION

- RWTH Aachen's VILLASnode commonly used for DP interface
- Delay is a major consideration
- Transients near coupling point are an issue



EMT MODEL VALIDATION

- Major differences in control approach from different vendors
- Most utilities/SOs now require PSCAD models from vendors (.dll) for DERs
- Growing awareness that accuracy / validation of these models is crucial
- Validation via field tests is usually limited in scope

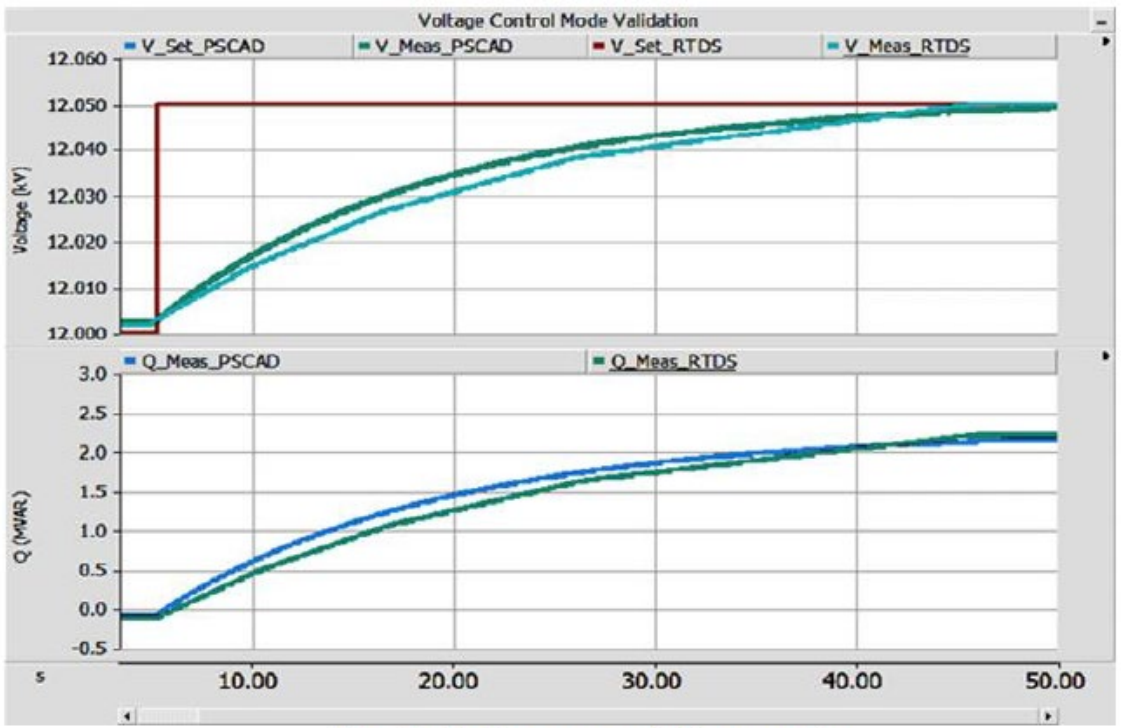
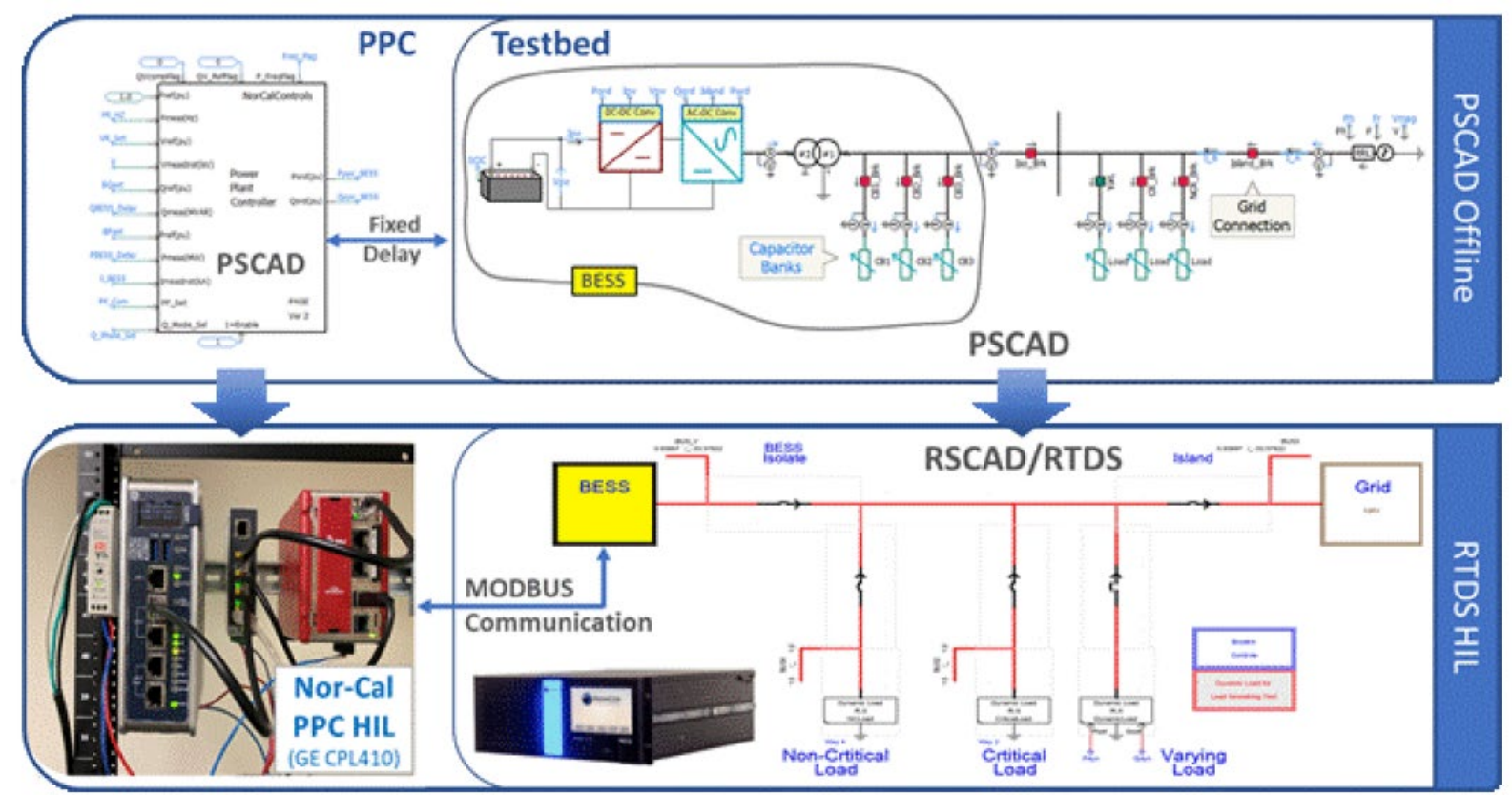


Fig. 3: Voltage regulation mode

Thank you Nayak for the images!

EMT MODEL VALIDATION

- Flexible, thorough, cost-effective validation of model against hardware
- Example: Nor-Cal Controls **(PPC manufacturer)**



Thank you Nayak for the images!

INTERACTIONS

- NERC's 2020 Technical Report on BPS-Connected IBR Modelling and Studies details the need to identify potential interactions between inverter controls, HVDC, protection, series-compensated circuits
- Generic models may hinder ability to accurately predict interactions/misoperations
- Potential control interaction is a major justification for HIL testing

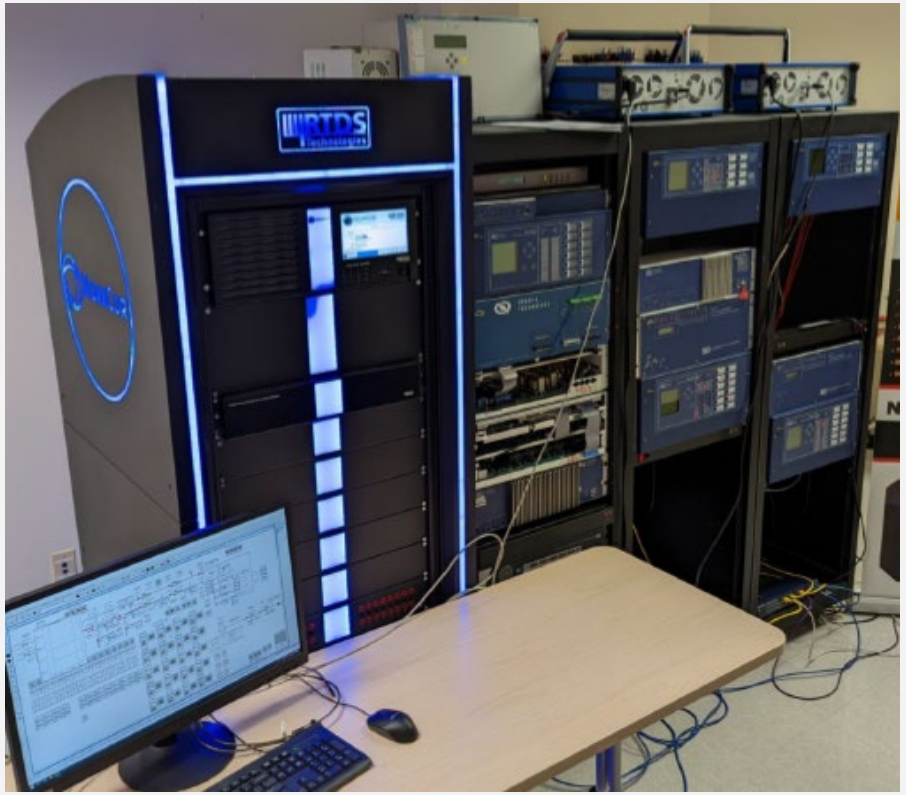


Photo courtesy of Quanta Technology

INTERACTIONS: PROTECTION AND IBRS

- Quanta Technology study of protection on a series-compensated 345 kV line tied to a Type IV wind farm facility

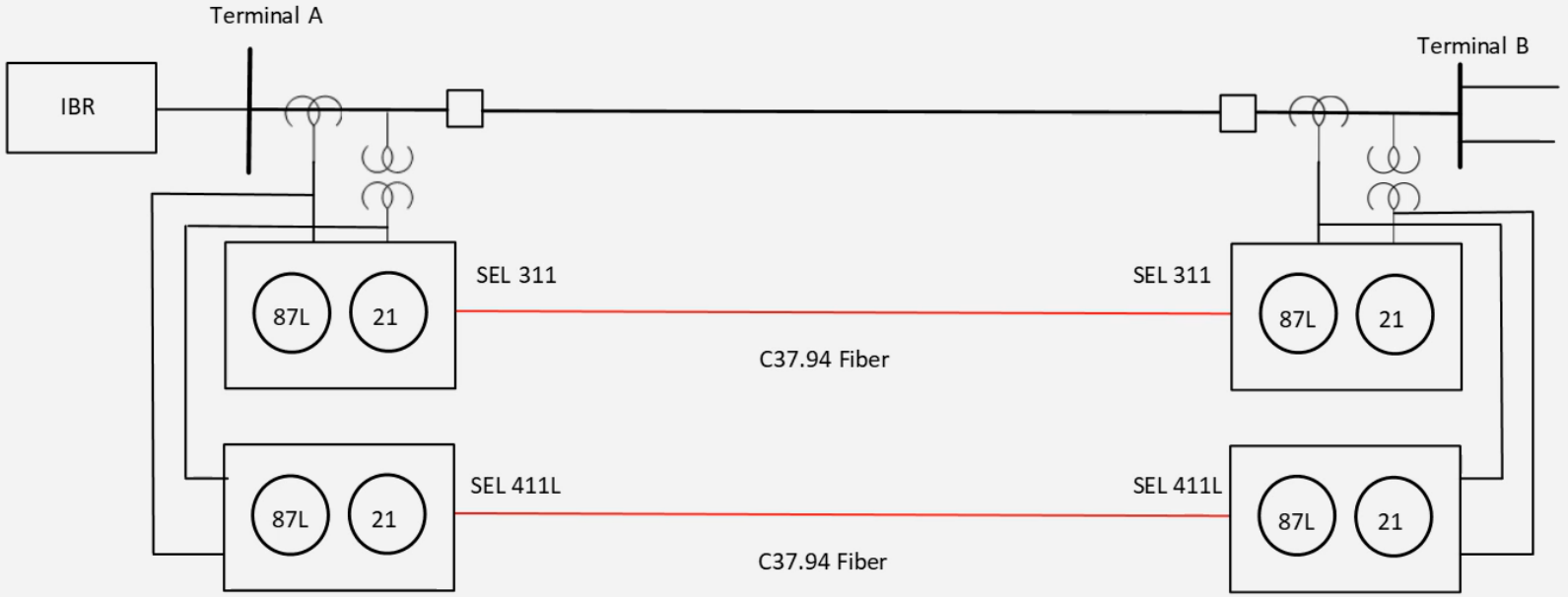


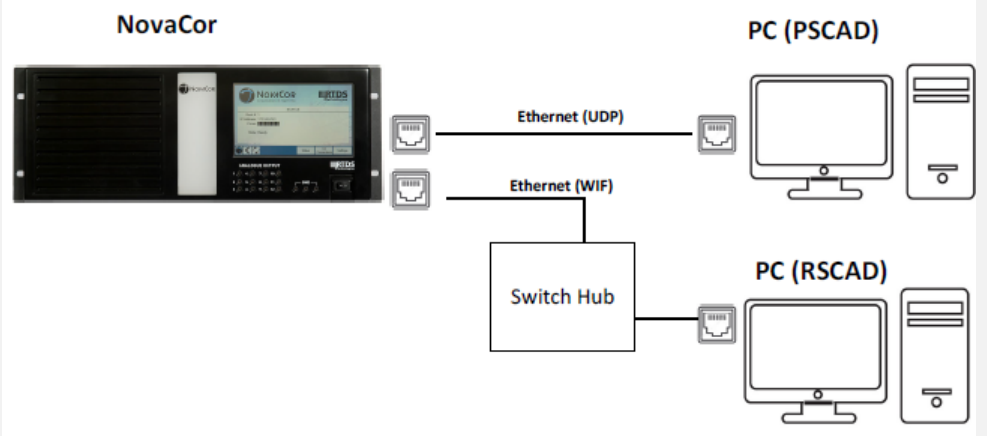
Image courtesy of Quanta Technology

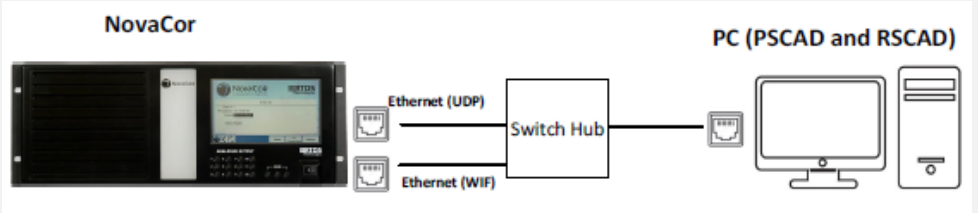
REAL-TIME BLACK BOX CONTROL

- Generic control models have limitations
- The GTSOC supports integration of vendor controls into the real-time simulation while protecting vendor IP (black box)
- Gives customer accurate control behaviour without needing the physical hardware in the HIL testbed, and has direct digital interface with the Simulator
- Key for de-risking interactions between IBRs, HVDC, protection, etc.

PSCAD RSCAD Co-Simulation in non-real time

- Useful for customers who are operating black boxed controls in PSCAD (DLLs) and have no means to migrate it to the GTSOC (i.e. OEM unable to develop control integration)
- Significant performance increases over an all-PSCAD simulation – much higher simulation efficiency
- Non-real-time, no I/O
- Currently only supports control interface (controls run on PSCAD, power system on RTDS)
- Power system interface via T-line is currently in the works

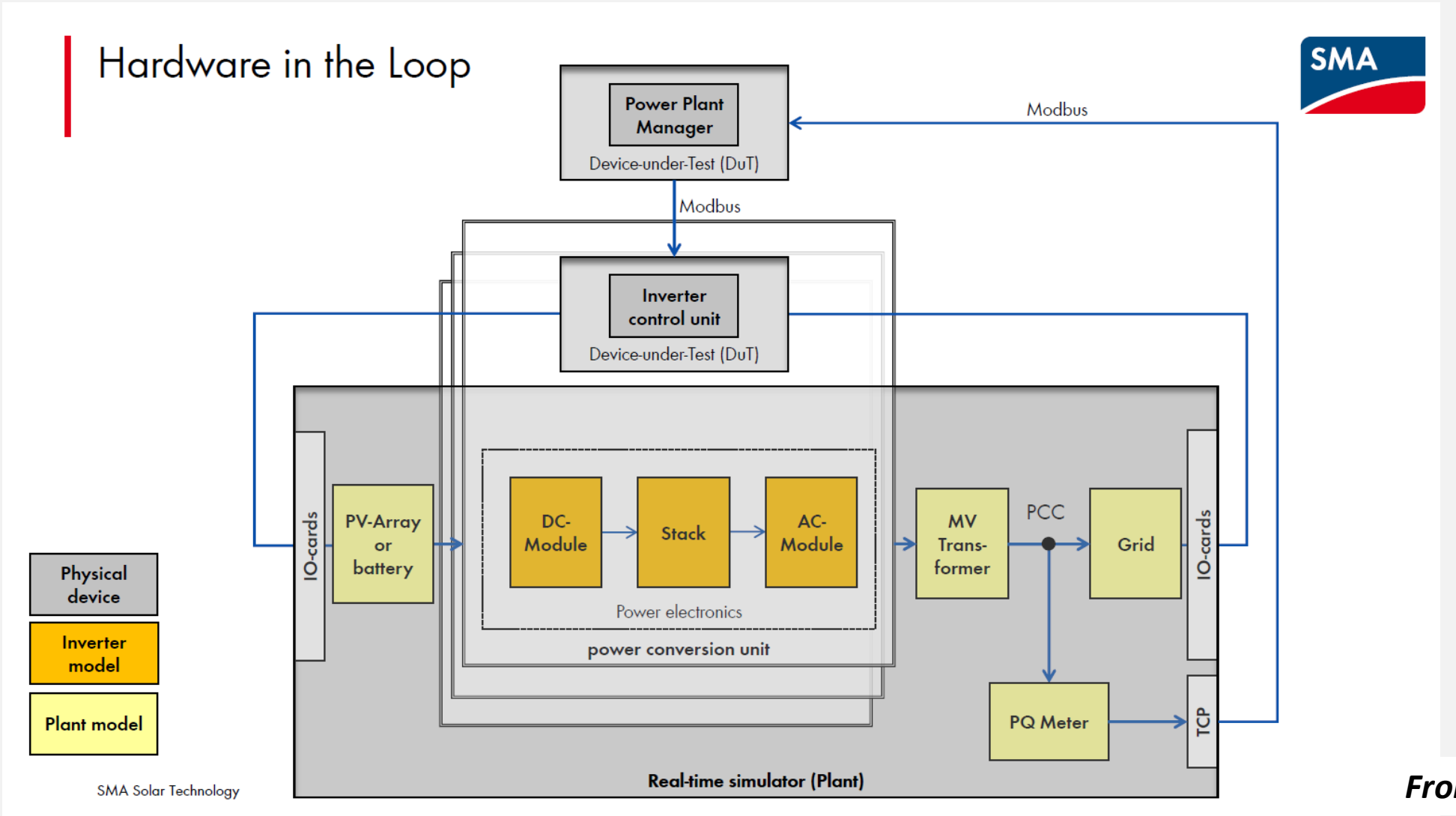




INVERTER MANUFACTURERS

- We are seeing increased interest from inverter manufacturers in using the RTDS to test their product
  - Qualification / factory tests
  - Firmware validation
  - Integration tests with customer equipment, which may be offered as a service

- Traditional HIL setup enables SMA to do qualification/factory tests and firmware validation, as well as integration tests with customer equipment which they offer as an engineering service

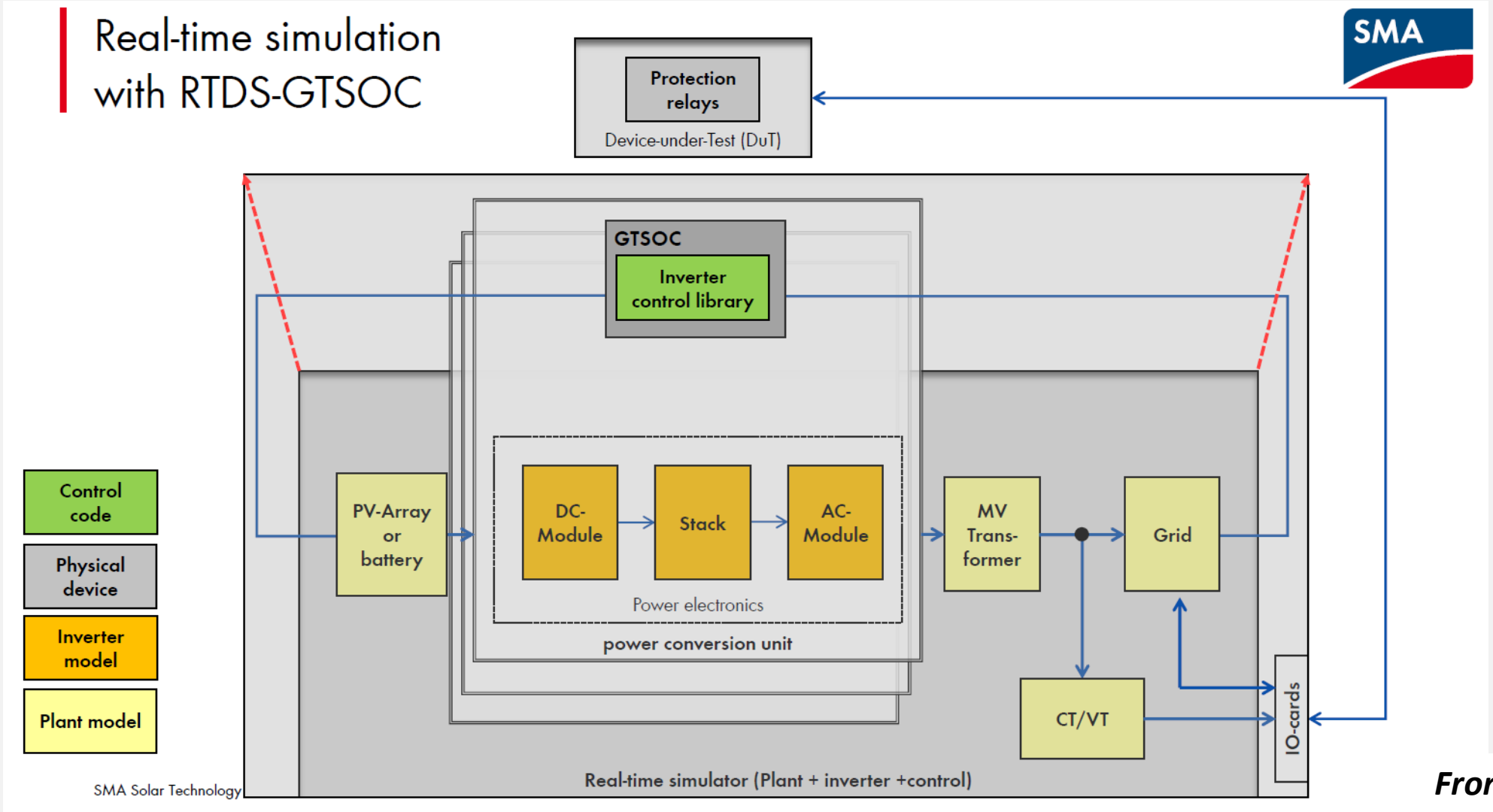


From SMA

INVERTER VENDORS – BLACK BOX CONTROL

- The need to have accurate models of inverters in the real-time simulation environment is growing, particularly for projects where interaction is a concern (HVDC, microgrids, protection, etc.)
- Real-time black box control simulation addresses this issue
- We have worked with SMA, Vestas, Siemens Gamesa, and more to get their controls running on the GTSOC

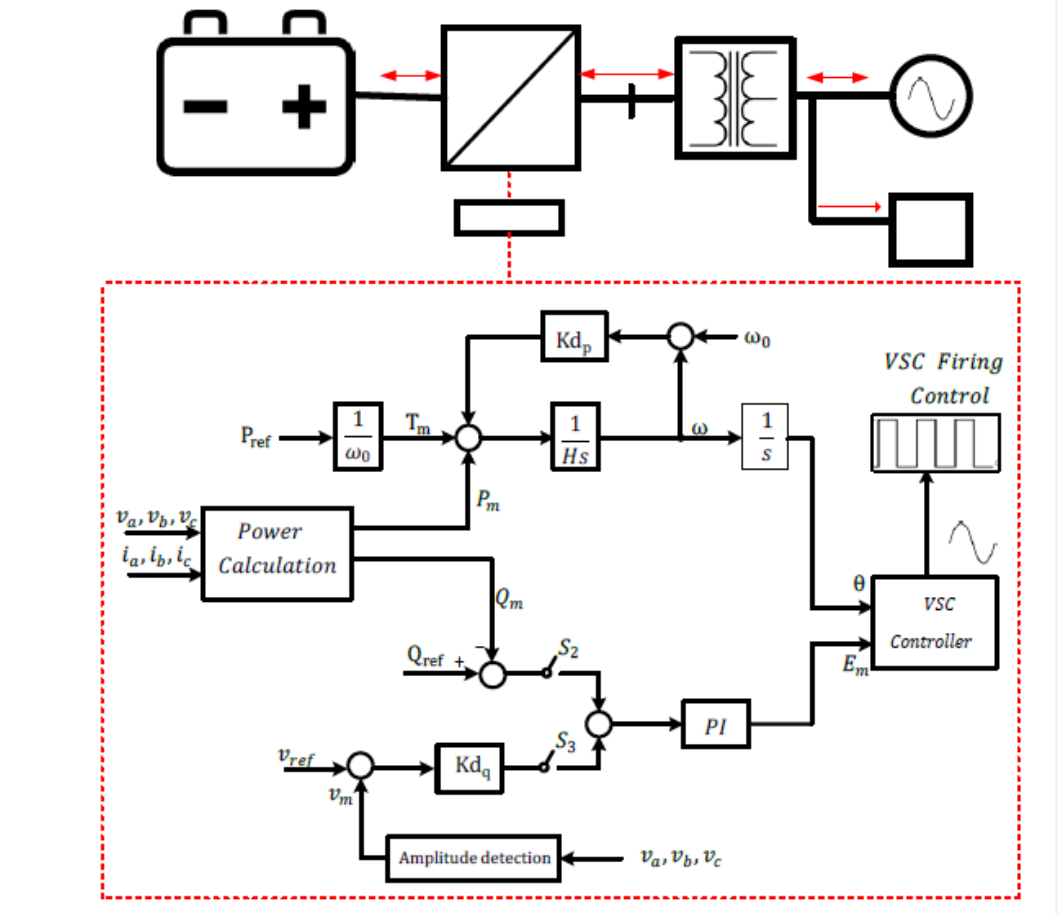
- GTSOC setup for situation where customer wants to test / tune protection relays in a microgrid scenario with a grid-forming SMA battery inverter



From SMA

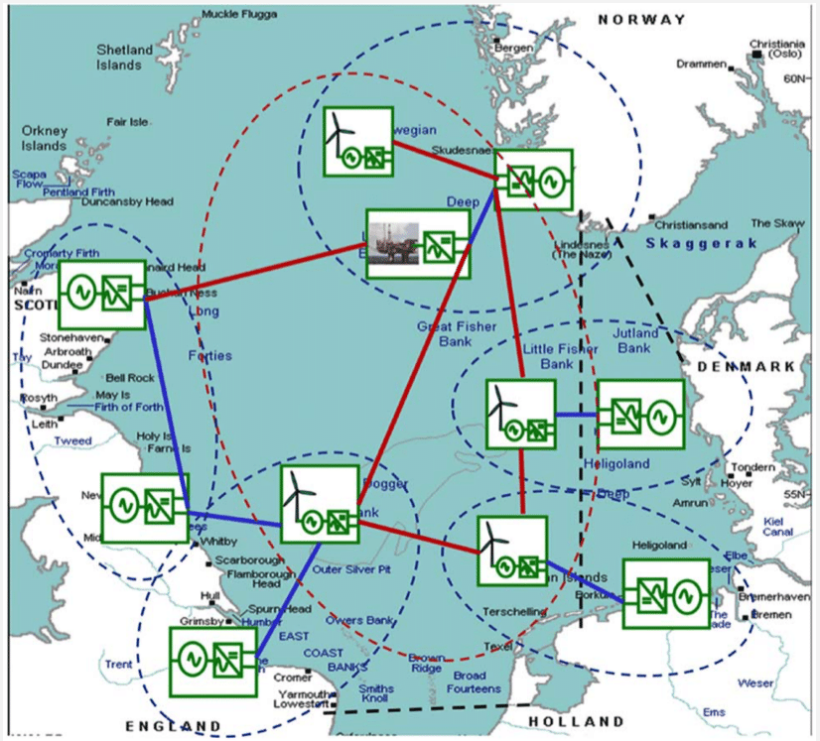
GRID FORMING CONTROL (GFC)

- Increasing need for IBRs to replace grid services / behaviour provided by conventional synchronous machines
- New, fully documented RTDS sample cases for droop control and virtual synchronous generator (VSG)



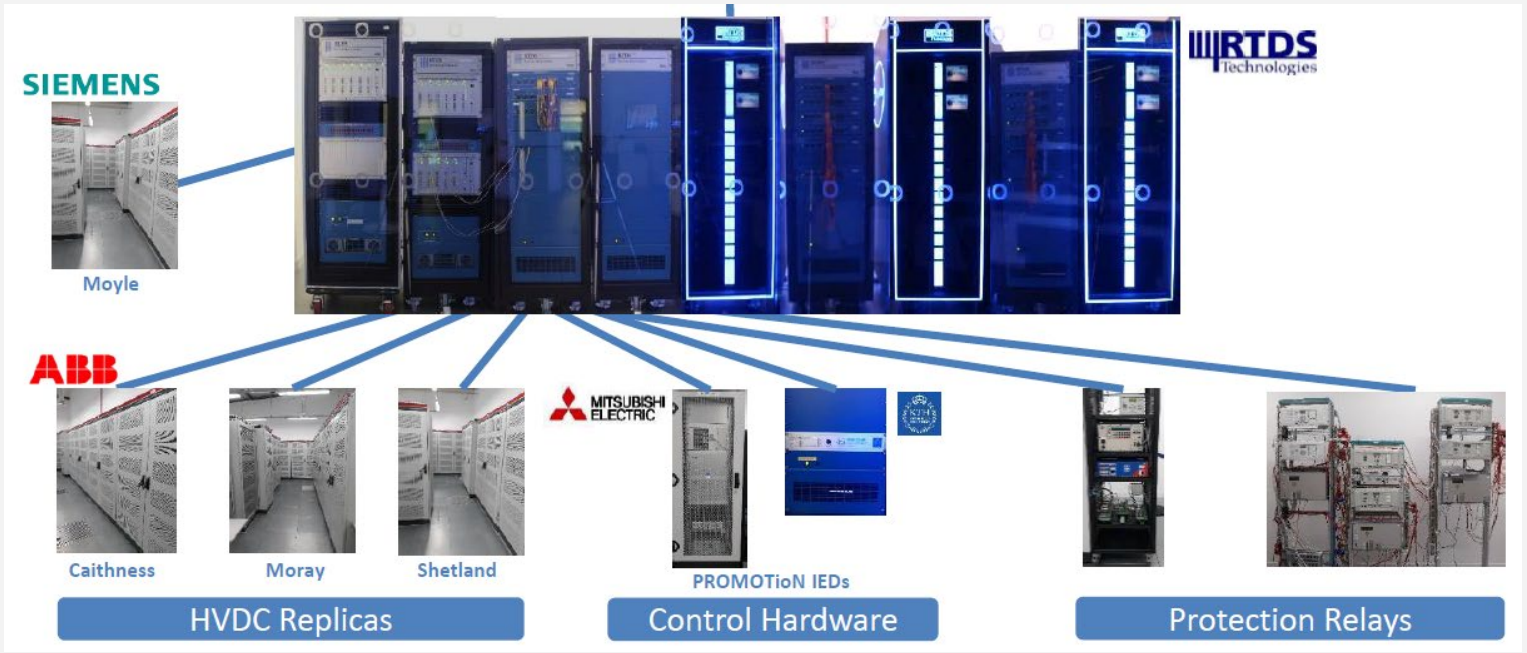
THE FUTURE IS HVDC

- Big market driver in Europe, China, and developing in the US
- Europe wants to build ~450 GW offshore wind by 2050; HVDC will play an important role in transmitting power to shore and interconnecting different countries and regions
- Multi-terminal, multi-vendor, multi-purpose HVDC grids are the future – will require massive amount of research, de-risking, and collaboration between stakeholders



NATIONAL HVDC CENTRE (UK)

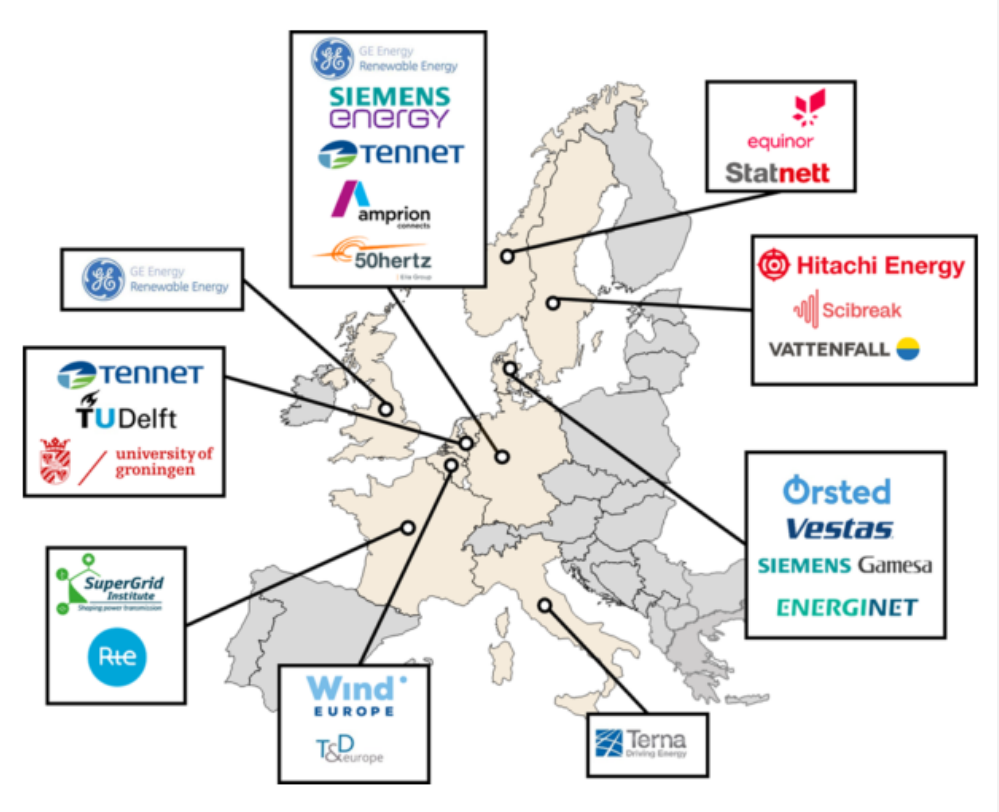
- 32 GB of new HVDC in Great Britain between now and 2031
- National HVDC Centre remains a global leader in HVDC simulation, replica testing, and knowledge sharing
- Project Aquila – interoperability demonstration project – more on this later in the meeting!



From the National HVDC Centre

INTEROPERA PROJECT

- InterOPERA research/demonstration project is aimed at enabling interoperability of multi-vendor HVDC grids in Europe
- Huge funding from Horizon Europe program
- Joint initiative of TSOs, wind developers and manufacturers, HVDC manufacturers, and universities
- Real-time physical demonstrator will involve HVDC replicas connected to the RTDS Simulator



Johan Sverdrup HVDC Project

- Offshore platform connected to Norwegian onshore grid (Equinor) via two parallel HVDC links
- 2-level VSC link supplied by Hitachi Energy and MMC-VSC link by Siemens
- HIL testing of replica control & protection cubicles, including global controller for parallel operation
- RTE International project – more on this later in the meeting!

GTSOC FOR HVDC

- Black box models
- HVDC controls are more intensive, requiring multiple cores and GTSOC units
- More on this later in the meeting!

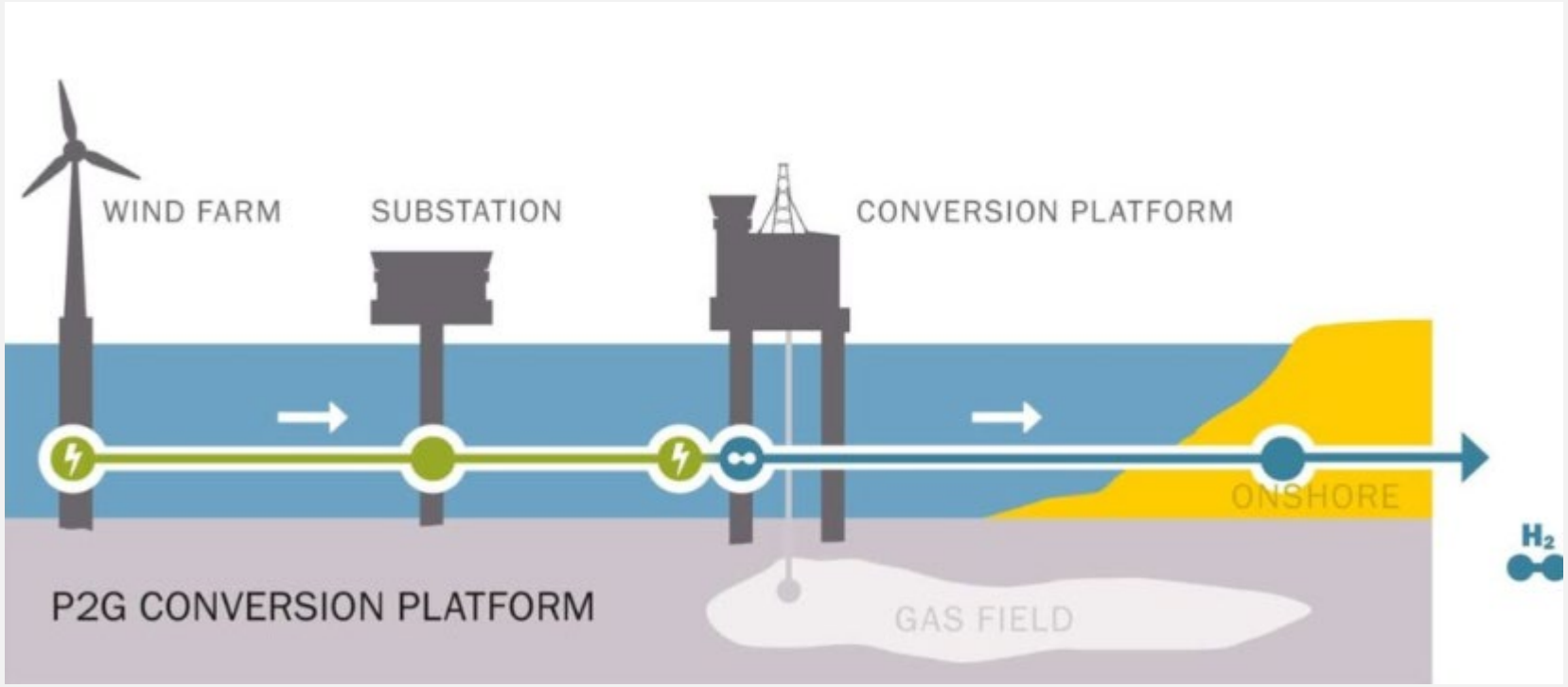
From the National HVDC Centre

NON-TRADITIONAL I/O REPLICAS

- Due to HVDC trends, heavy use of replica simulators by utilities/SOs is expected; need for multiple replicas in one physical space
- Interest in reducing physical size of replicas – I/O cubicles are the most effective route
- Reduce or eliminate the need for I/O cards via digital connection between simulator and control replica via Aurora / EtherCAT

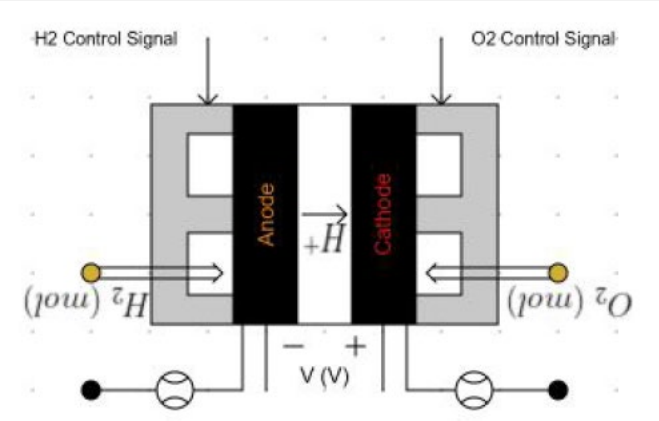
HYDROGEN – ENERGY ISLANDS

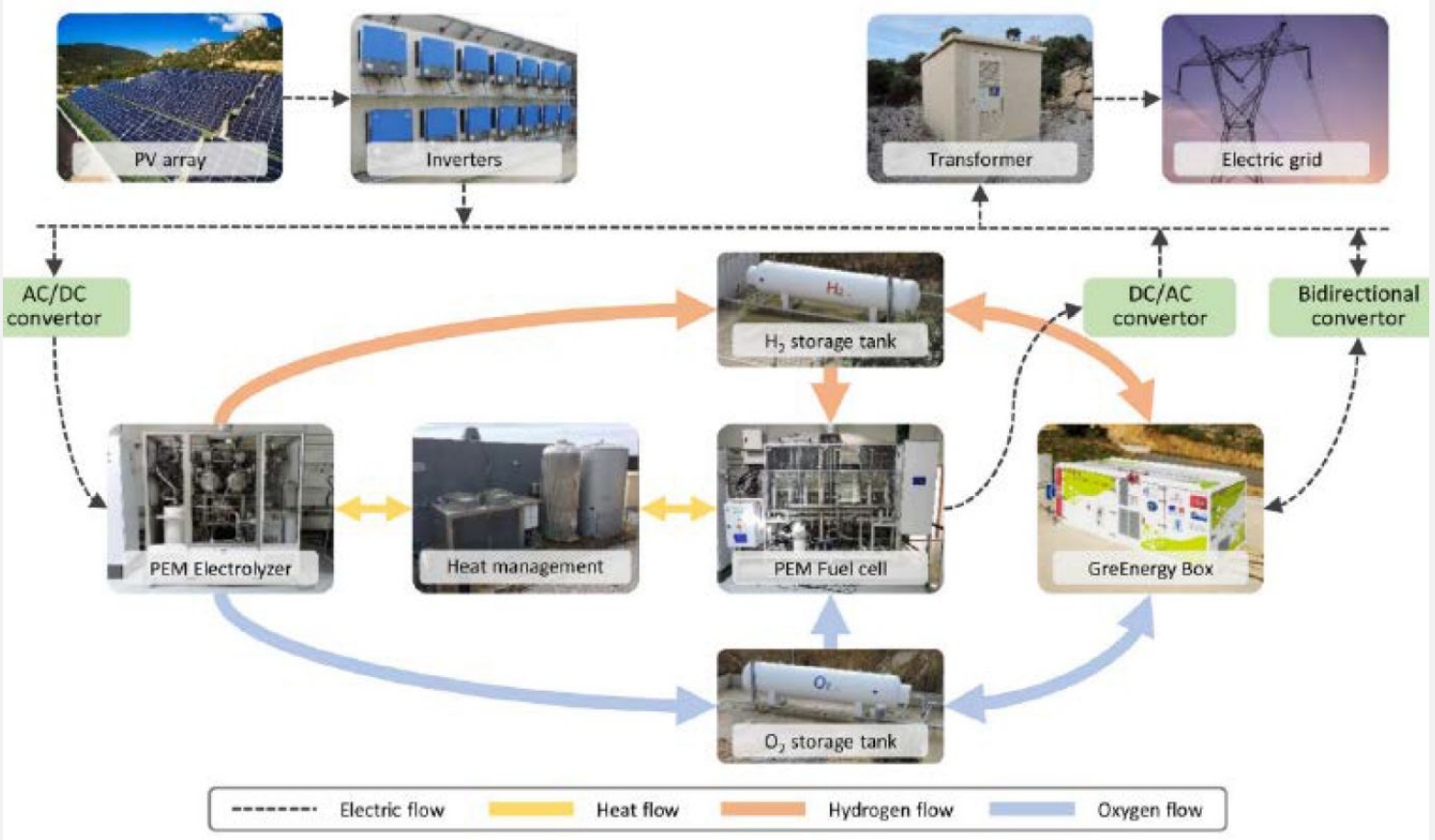
- Offshore energy islands – co-locating hydrogen production with HVDC stations
- Facilitates decarbonization of industries such as steel, ammonia, petroleum production (no need to reconvert to electricity onshore)



HYDROGEN – MULTI-ENERGY SYSTEMS

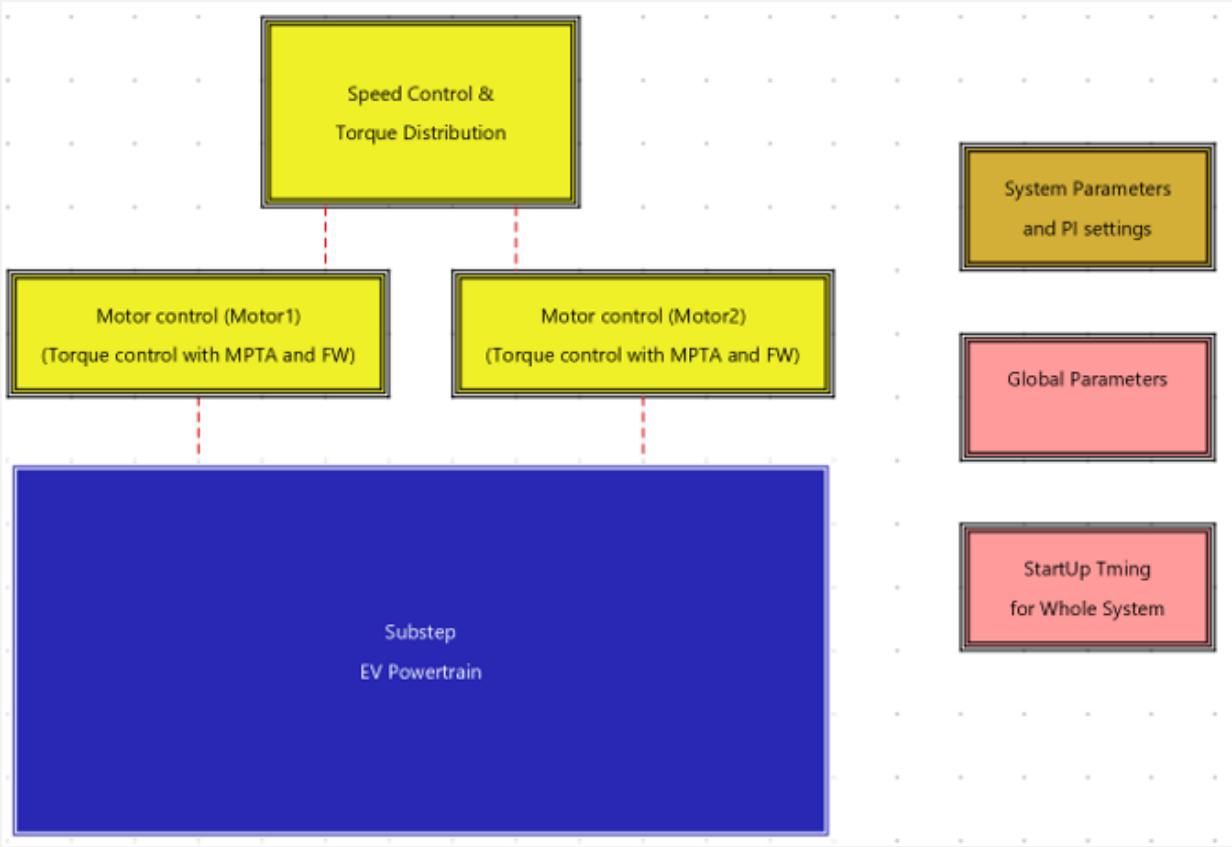
- Growing interest, particularly in Europe, in hydrogen development
- New models and cases in RSCAD for multi-energy flow systems





ELECTRIC VEHICLES

- We have had vehicle and charger models for a long time but have only been focused on vehicle-to-grid (V2G) applications, i.e. high-level impact on the network
- Growing interest in detailed EV simulation
- Developing powertrain model in RSCAD
  - Battery pack
  - DC-DC converter
  - DC-AC converter (motor drive)
  - PMSM (motor)

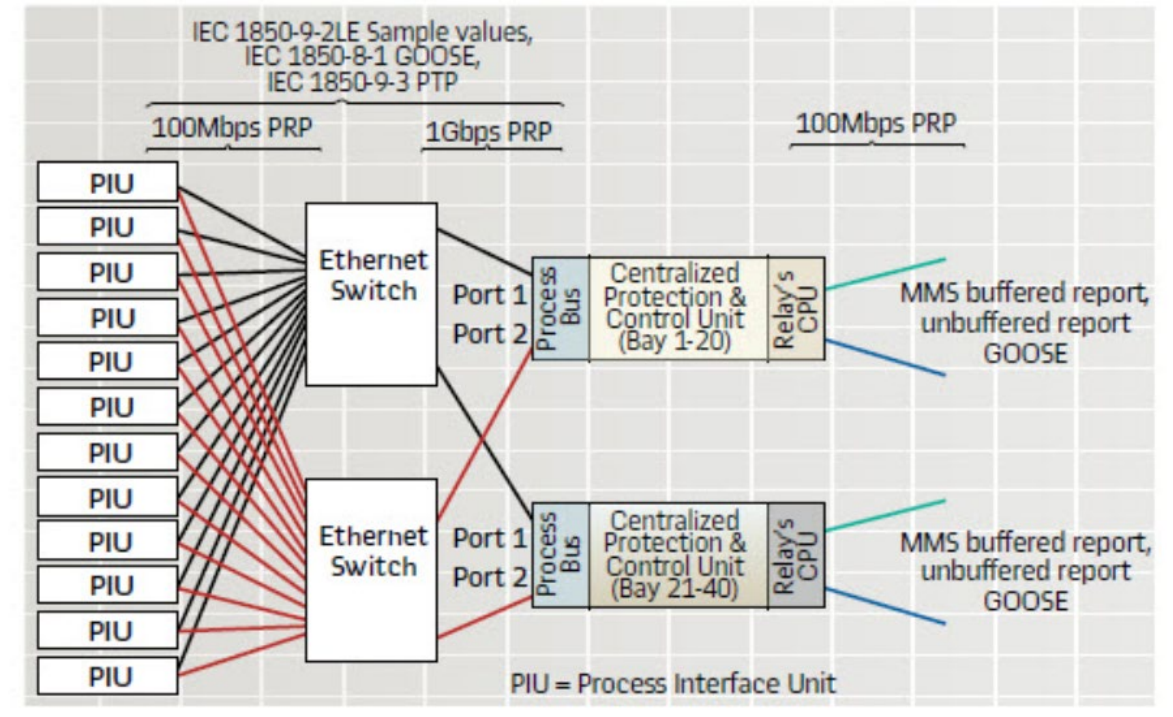


DISTRIBUTION SPACE

- Increasing interest in using the RTDS Simulator for grid-edge distribution applications including ADMS testing (VVO, FLISR)
- More and more software and IoT companies are aware of our technology when we visit distribution conferences

CENTRALIZED PROTECTION

- Growing adoption of digital substations has prompted interest in centralized substation protection and control
- Based on IEC 61850 GOOSE and Sampled Values; high number of SV streams may be necessary to protect many bays simultaneously
- Wide-area functionality via synchrophasor data
- Cybersecurity and communications hardiness are very important
- Implementing support for PRP and HSR redundancy protocols on the GTNETx2
- Implementing support for MU representation with combined GOOSE, SV, MMS

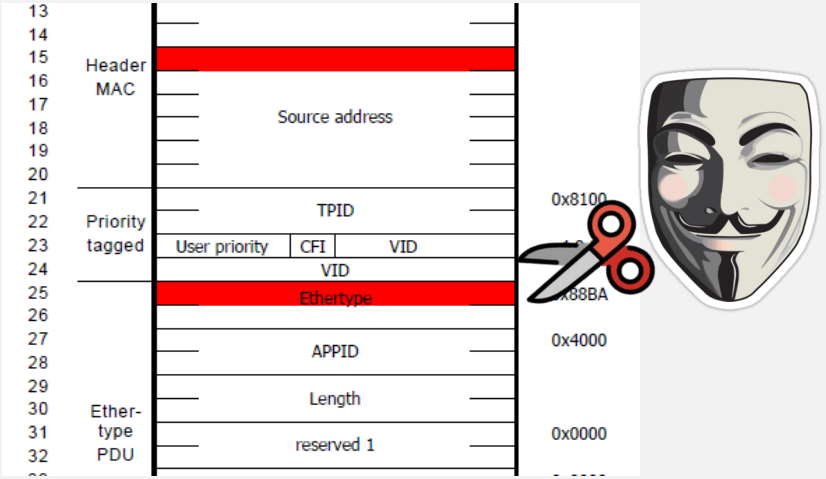


From PAC World

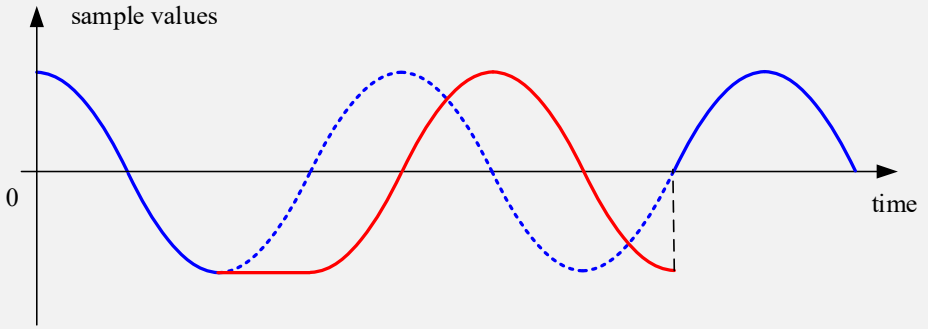
GTFPGA-SV

- 16 simultaneous SV streams with a wide range of sampling rates supported
- Sampled Values Manipulation feature allows for convenient testing of centralized protection against network disruptions and cyber attacks

Data Manipulation

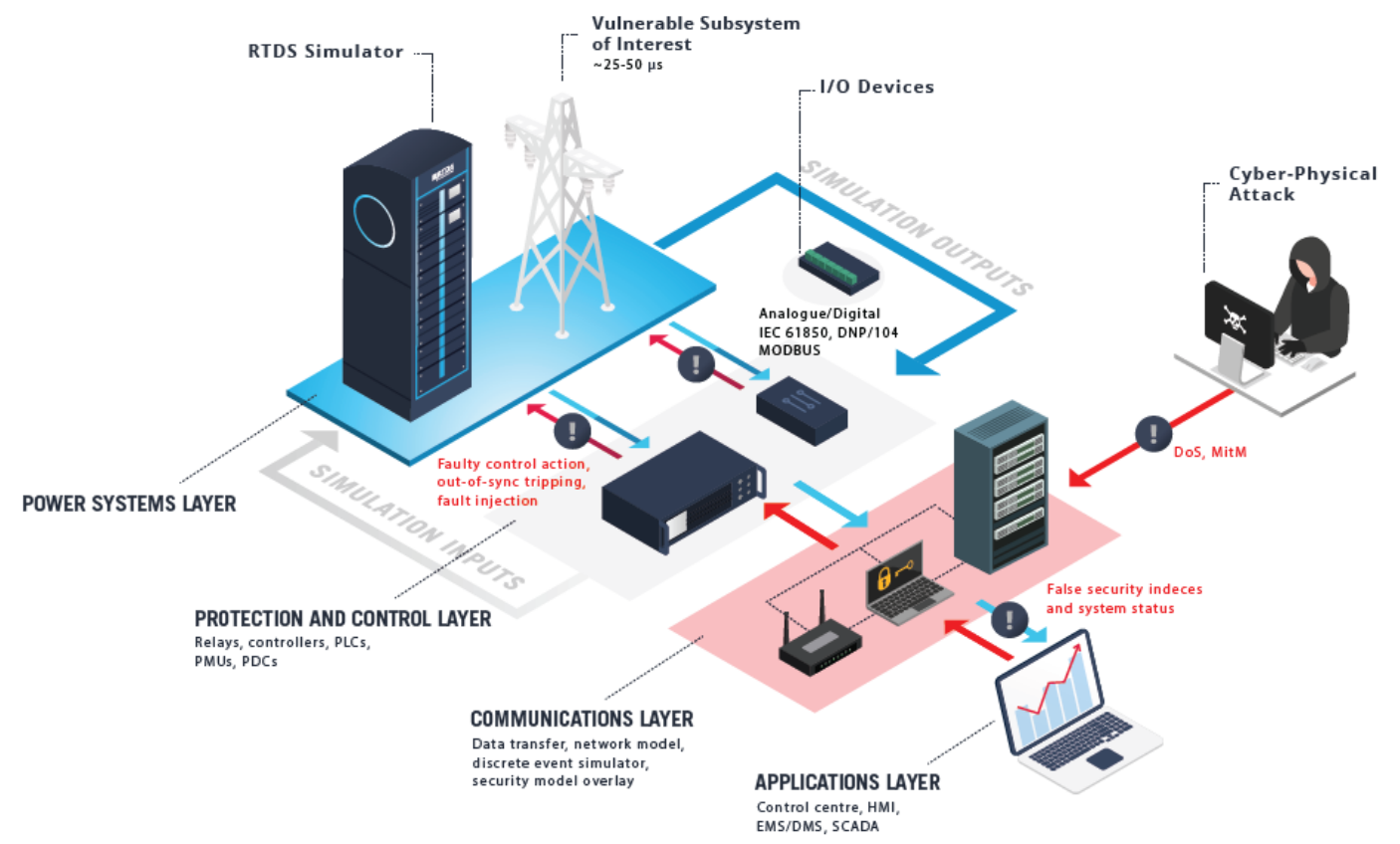


Stream Manipulation



OTHER CYBERSECURITY PROJECTS

- Cybersecurity remains a topic of interest for the power industry
- Typically the RTDS serves as a means to measure the impact of cyber attacks on power system stability and/or test automation
- If you are pursuing this topic and can share information, please send us your papers/progress so we can better understand and promote use cases



QUESTIONS?