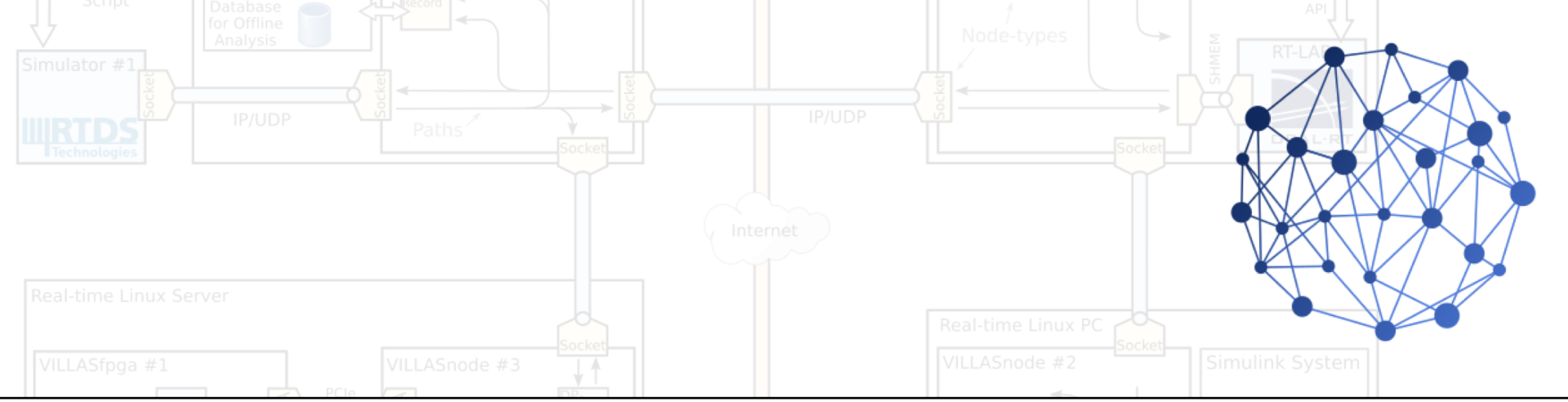


VILLAS concept

Virtually Interconnected Laboratories for LArge systems Simulation/emulation

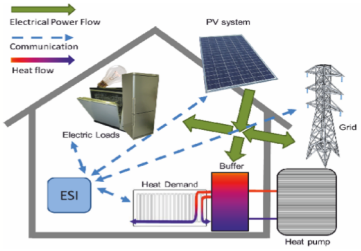
Technical Workshop of the ERIGrid Project

13.09.2018
Oldenburg, Germany

Prof. Antonello Monti

ACS | Automation of Complex Power Systems
E.ON Energy Research Center
RWTH AACHEN UNIVERSITY

Institute for Automation of Complex Power Systems
Research Areas



Applications

- Smart Cities
- Future Energy Networks
- Center for Wind Drives
- Future Internet

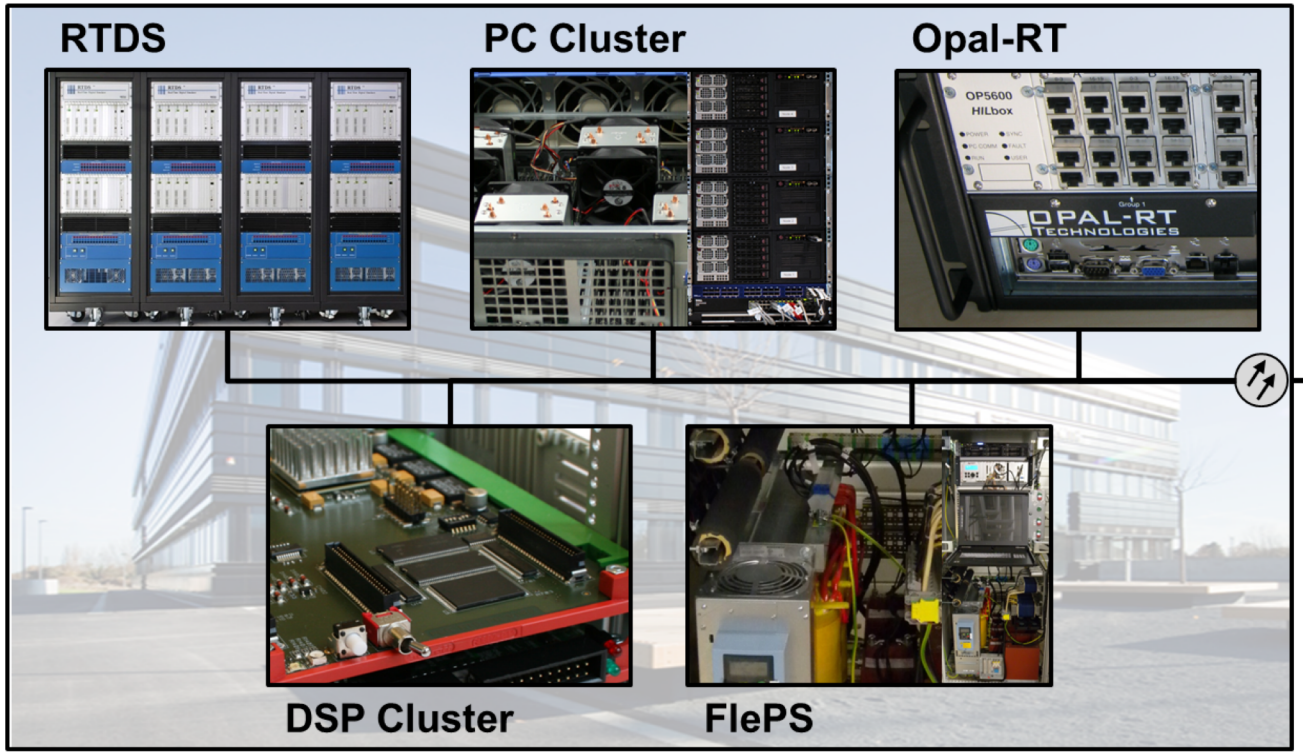
Grid Operations

- Fundamentals of Grid Dynamics
- Network Stability
- Hybrid DC/AC Networks
- Grid Monitoring
- Grid Automation
- Integration of Renewables

ICT 4 Energy

- Energy as data-driven systems
- Distributed Computing for Complex System Simulation
- Distributed Intelligence for Energy Systems
- Cloud applications for energy
- Real-Time Systems

Real Time Simulation Lab at ACS



External Testing facility

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External Interconnections

Sintef, Norway

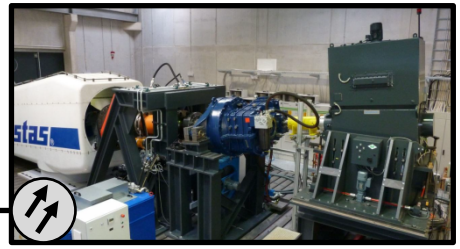
ACS Real Time Lab

5 MW PGS Test Bench

Uni. South Carolina, US

Joint Research Center, EU

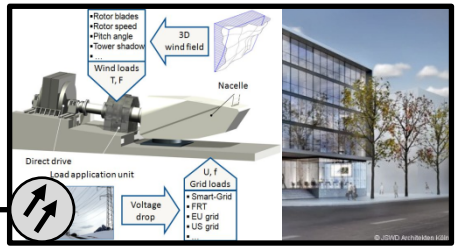
1 MW On-Shore Wind Turbine Test Bench



Politecnico di Torino, Italy

Idaho National Lab, USA

4 MW On-Shore Wind Turbine Test Bench



Waterford Institute of Technology Ireland

Politehnica din Bucuresti Rumania

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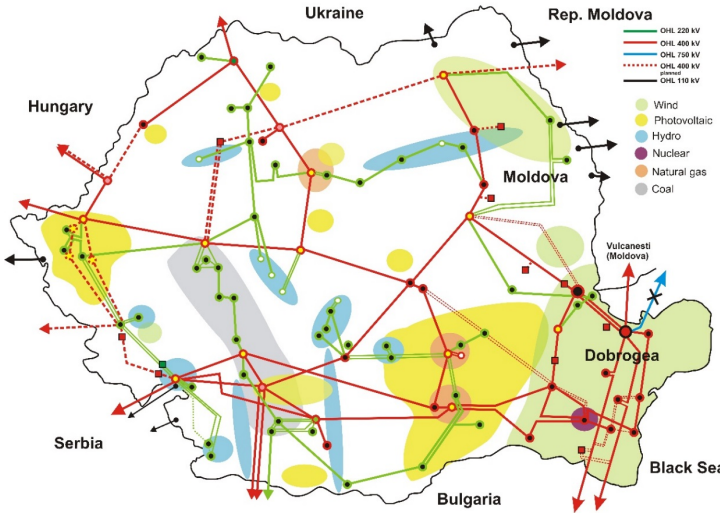
Real-time simulation capacity



Simplified diagram of the Romanian transmission system
Source: TransE

RTDS PB5 card
Source: rtds.com

The Romanian transmission system alone has already more than **1500 network 3ph nodes**

One RTDS PB5 can handle ~30 3-phase network nodes. One rack with four PB5 cards
→ **120 nodes in total**

Global Power Grid

- Ultrahigh-voltage dc links between continents to build Global Power Grid
- How such a grid will operate?
  - Large-scale and holistic simulation and testing environment for design and assessment
  - A flexible framework for collaboration between research entities, industries and utilities

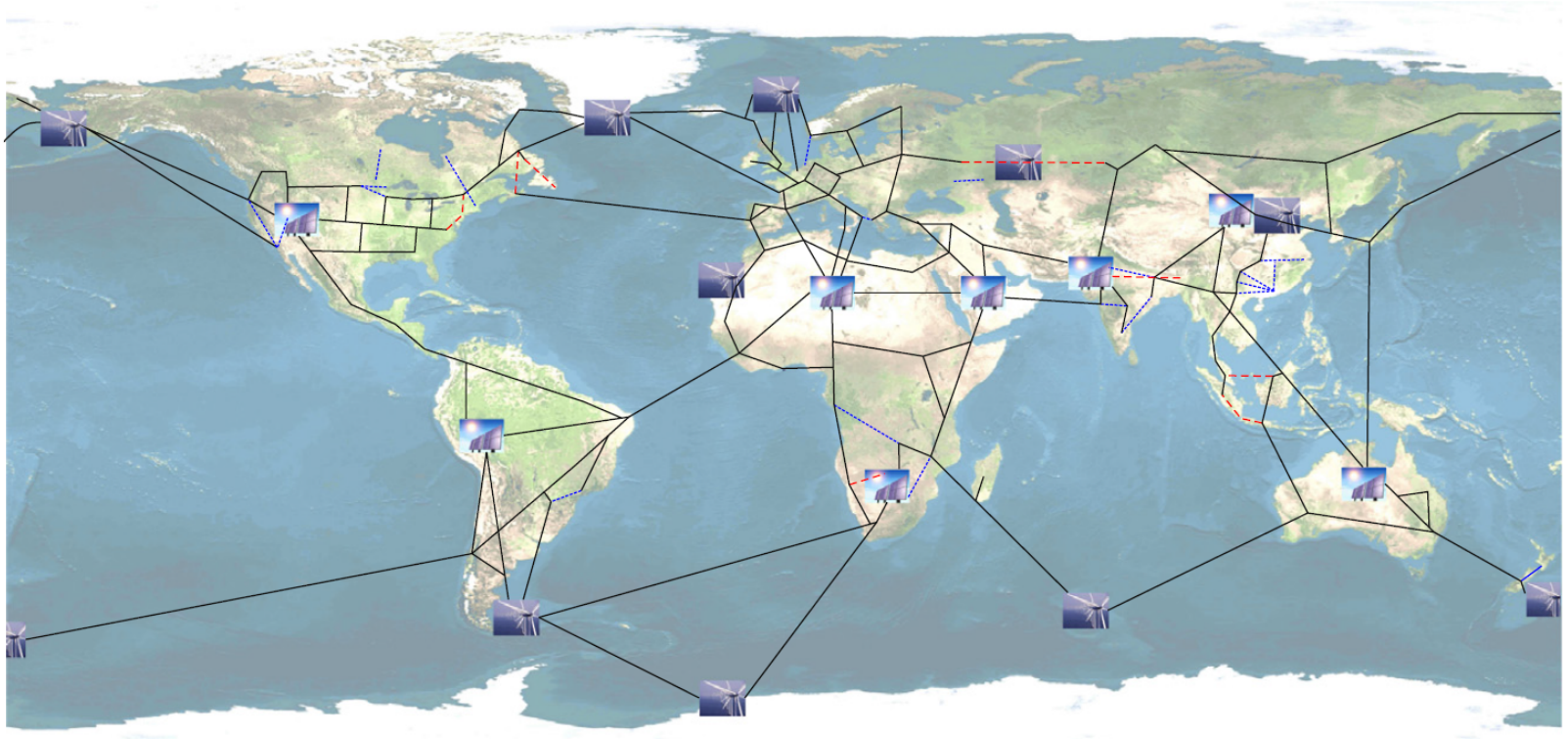
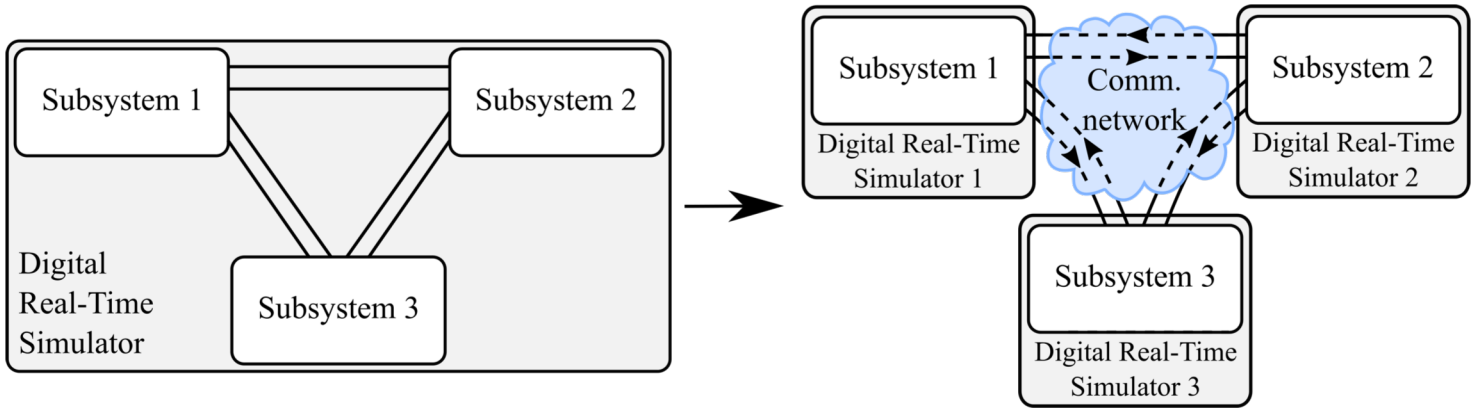


Illustration of a possible Global Grid

Jones, Lawrence E. *Renewable Energy Integration: Practical Management of Variability, Uncertainty and Flexibility In Power Grids.* Burlington: Academic Press, 2014.

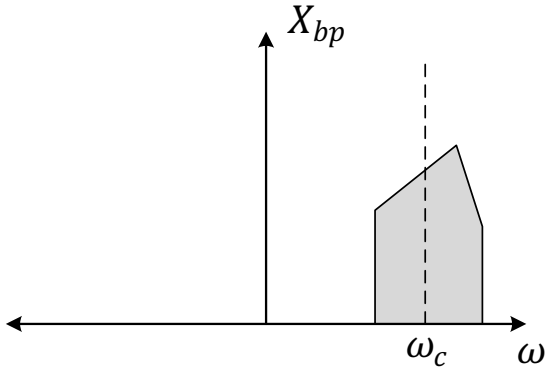
Our Solution: Global Real-Time Simulation

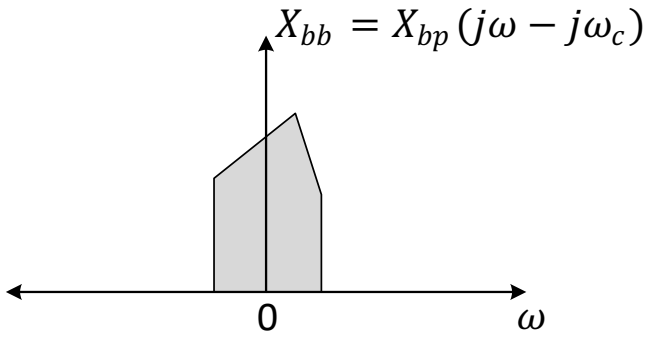
- Distributed co-simulation to share simulation capacity and hardware by coupling real-time simulators
- Distributed simulation allows participants to keep their data confidential
- Still **real-time** to interface with real hardware for prototyping
- Latency between simulators and simulation sites caused by distance between labs
- Different simulators generate different results and there is no reference implementation
- Compatibility with existing grid descriptions (CIM)
  → new simulator called DPsim as part of simulation platform

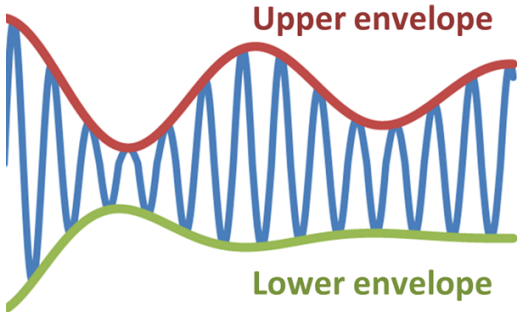


Dynamic Phasors for Decoupling Large-Scale Distributed Simulation

- Fourier spectrum of real-valued signal is symmetric around the $\omega = 0$ axis → negative part can be omitted
- We could shift the bandpass signal X_{bp} by a certain frequency which results in a baseband representation
- The resulting signal still contains all the information of the original signal except for the carrier frequency
- In the time domain the baseband signal *envelopes* the original signal







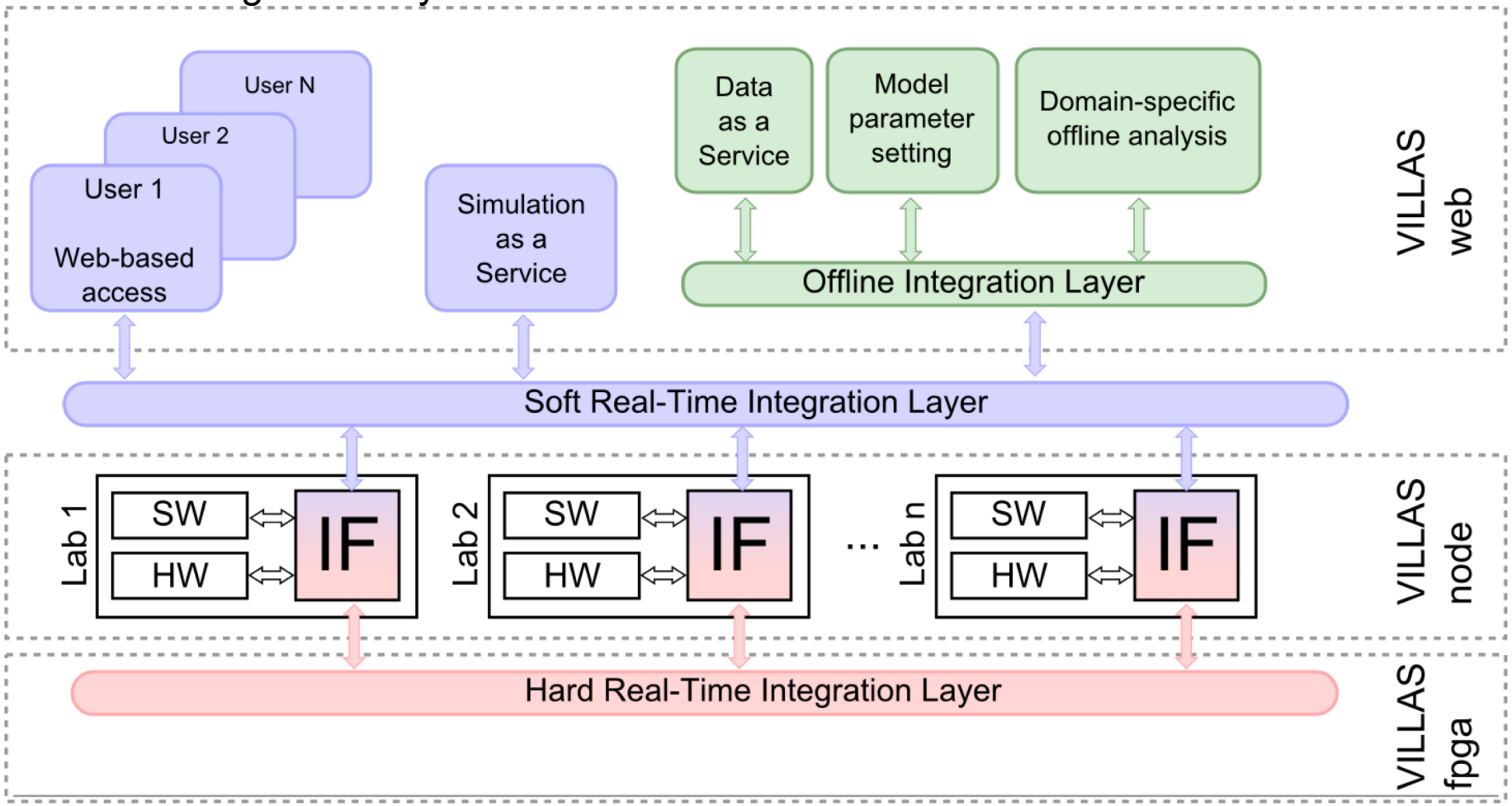
By Brews ohare - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=19014255

Ingredients for a global virtual testbed

- A common model format
  for exchanging and retargeting models
- Flexible interfaces
  for interconnecting a heterogenous set of simulators and devices
- A common user interface
  for collaborative editing, control and monitoring
- Open solvers
  for verifiable and scalable simulations

VILLASframework
Integration Layers

- Hard Real-Time Integration Layer
- Soft Real-Time Integration Layer
- Offline Integration Layer



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VILLASframework
Framework for Virtual Integration of Laboratories

- VILLAS - **V**irtually **I**nterconnected **L**aboratories for **LA**rge systems **S**imulation/emulation
  - a flexible integration of the resources available at each laboratory
  - a flexible utilization of an infrastructure as a whole

- VILLASframework aims at providing a specific set of interfaces and services
  - hard and soft real-time interfaces
    - = integration of geographically dispersed hardware and software assets for joint operation in a single experiment
  - high-level interfaces such as a user interface, an interface for data logging
    - = interactions with an experiment and post-processing of results for further analyses
  - high-level services, such as Simulation as a Service, Data as a Service
    - = flexible access for third parties to leverage utilization of the infrastructure

VILLASframework

- Open source tool kit for distributed real-time simulation (GPLv3 license)

VILLASnode

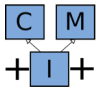
- A gateway for real-time simulation data

VILLASweb

- A web-interface for planning, executing and controlling distributed simulations

DPsim

- A real-time simulation kernel for the EMT / DP domain



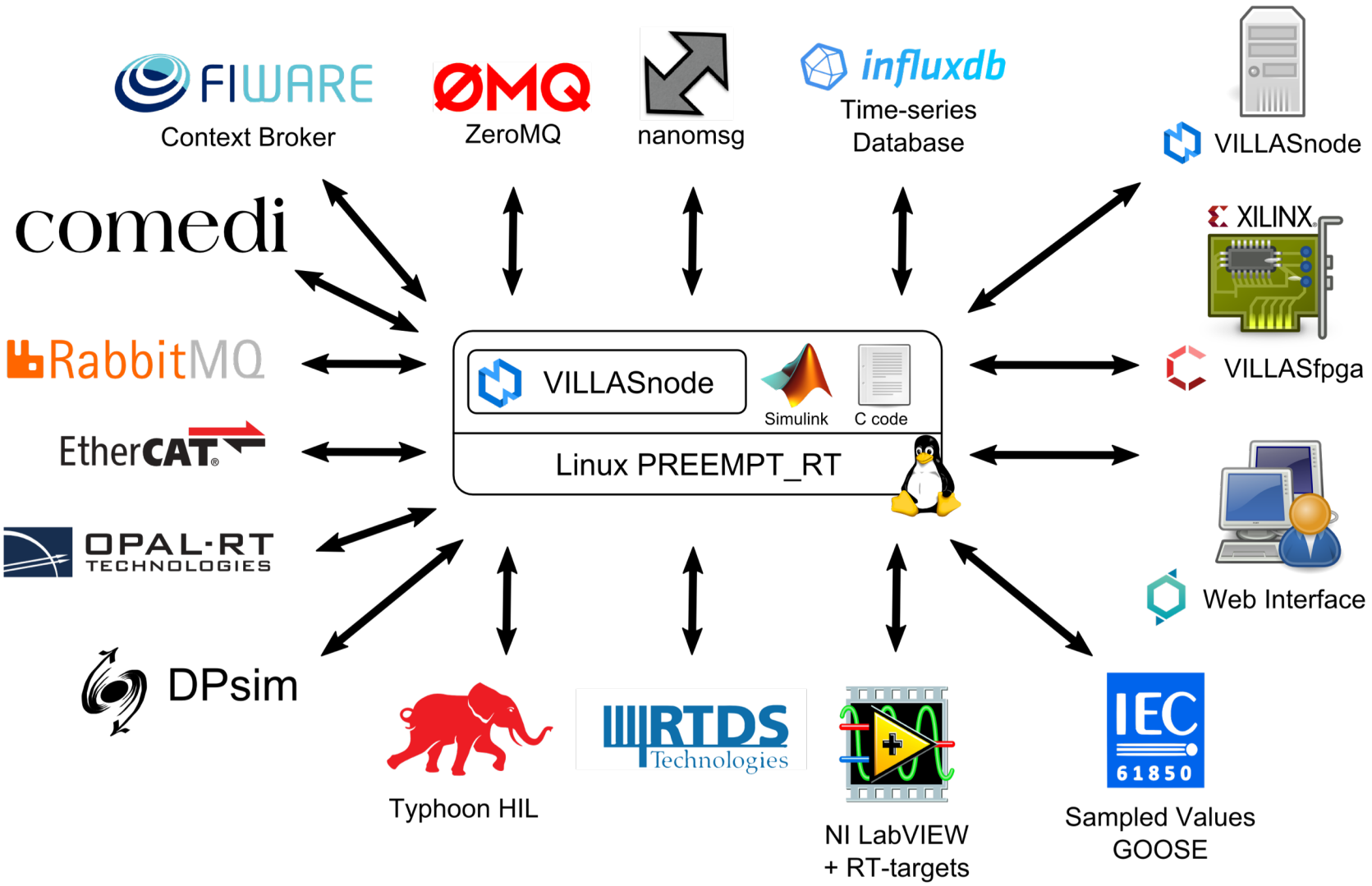
CIM++

- A library for parsing and compiling CIM to Modelica, GLM

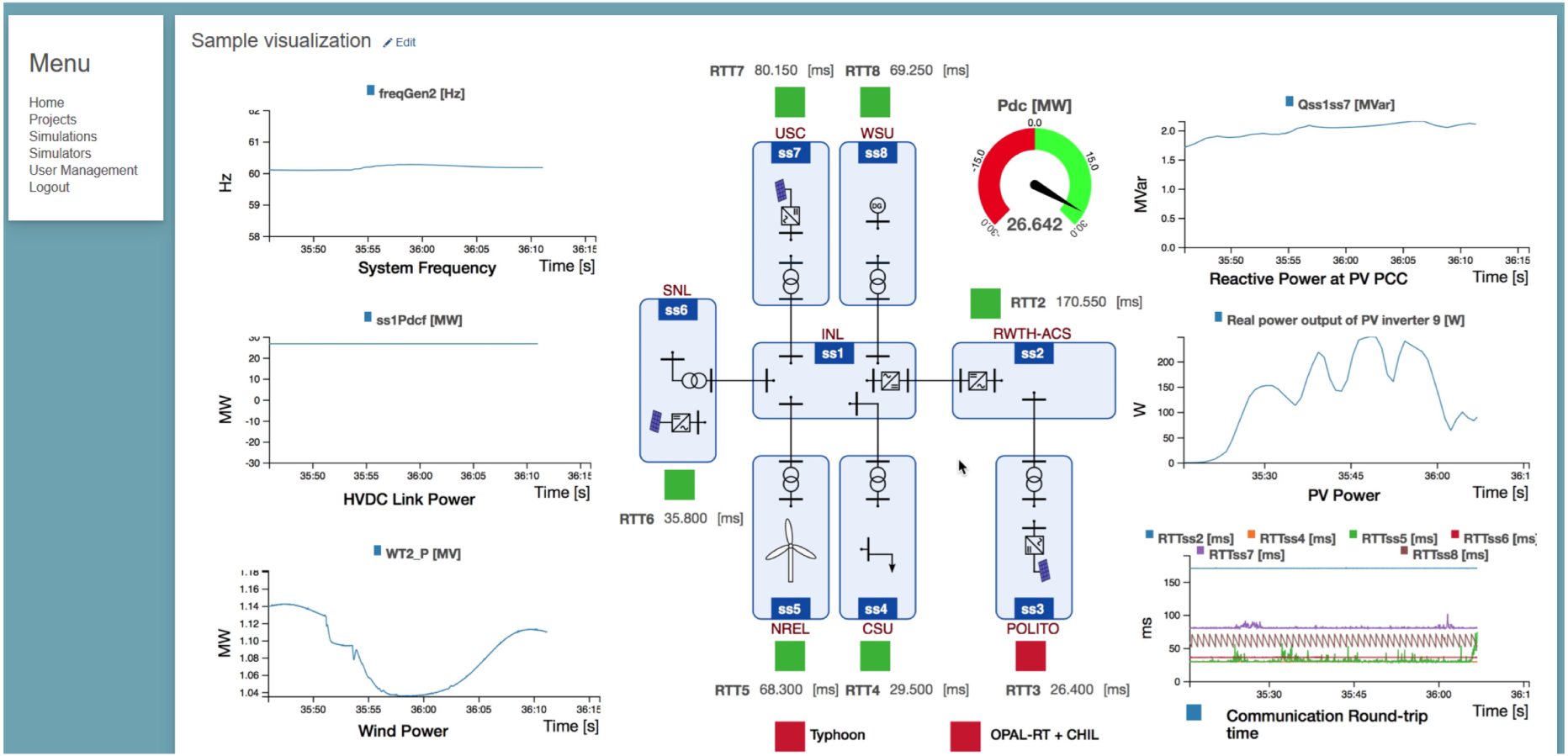
Pintura

- Web-based Graphical Editor for CIM models

VILLASnode


FIWARE
Context Broker
ØMQ
ZeroMQ
nanomsg
influxdb
Time-series
Database
VILLASnode
comedi
XILINX
RabbitMQ
VILLASnode
Simulink
C code
VILLASfpga
EtherCAT
Linux PREEMPT_RT
OPAL-RT
TECHNOLOGIES
Web Interface
DPsim
Typhoon HIL
RTDS
Technologies
IEC
61850
NI LabVIEW
+ RT-targets
Sampled Values
GOOSE

VILLASweb
Live monitoring



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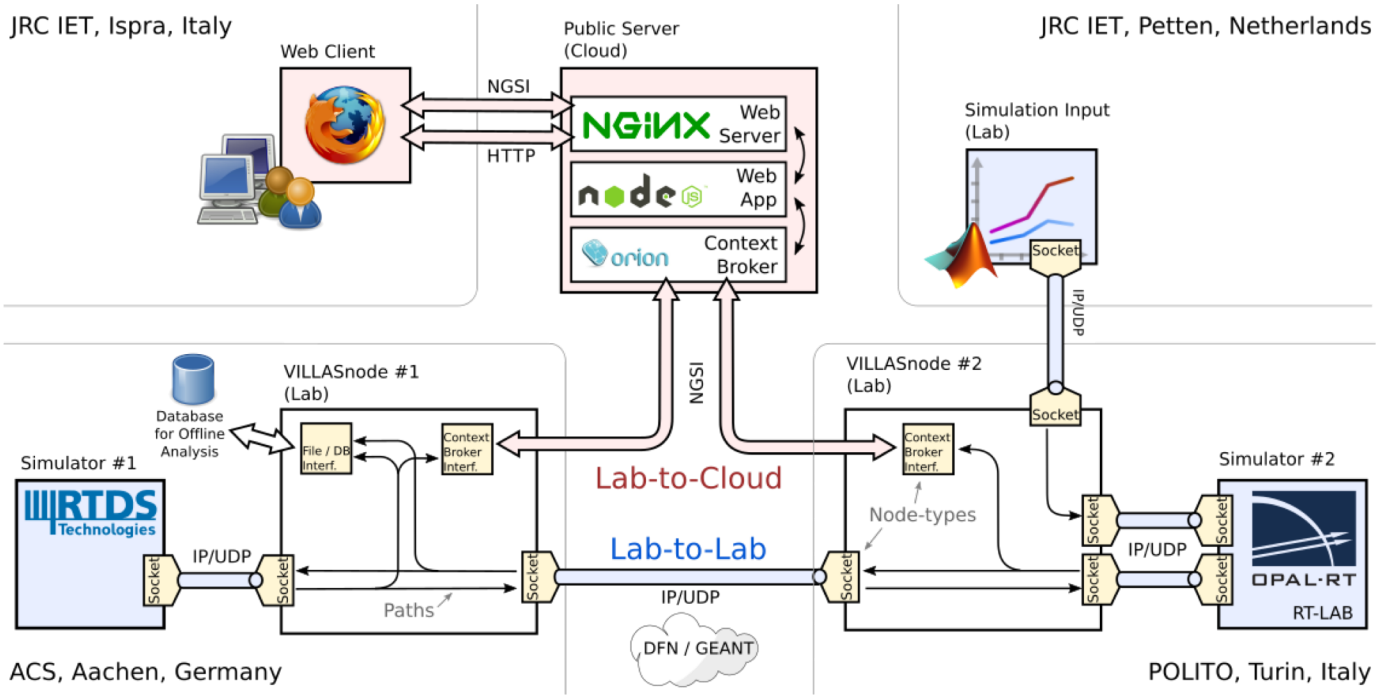
History of Distributed Co-Simulation & Lab Links

- 2013-2017 ProOfGrids
  - SINTEF, RWTH
- Oct 2015 ERIC Lab
  - JRC, POLITO & RWTH
- Sept 2015 VILLAS (RWTH Aachen)
  - FZ Jülich, RWTH Aachen
- Sept 2017 Global RT-SuperLab
  - INL, NREL, SNL, USC, CSU, WSU, POLITO, RWTH
- RESERVE
  - POLITO, UPB, WIT, RWTH
- 2018 InFIS
  - RWTH Aachen

VILLASframework for ERIC Lab Demonstration

- ERIC Lab - European Real-time Integrated Co-simulation Laboratory
  - A network of European laboratories for a science-based support of policy decision making toward future electricity systems
- The concept has been demonstrated in a collaboration with Politecnico di Torino (POLITO) and Energy Security, Systems and Market Unit of the EC Joint Research Center (JRC)



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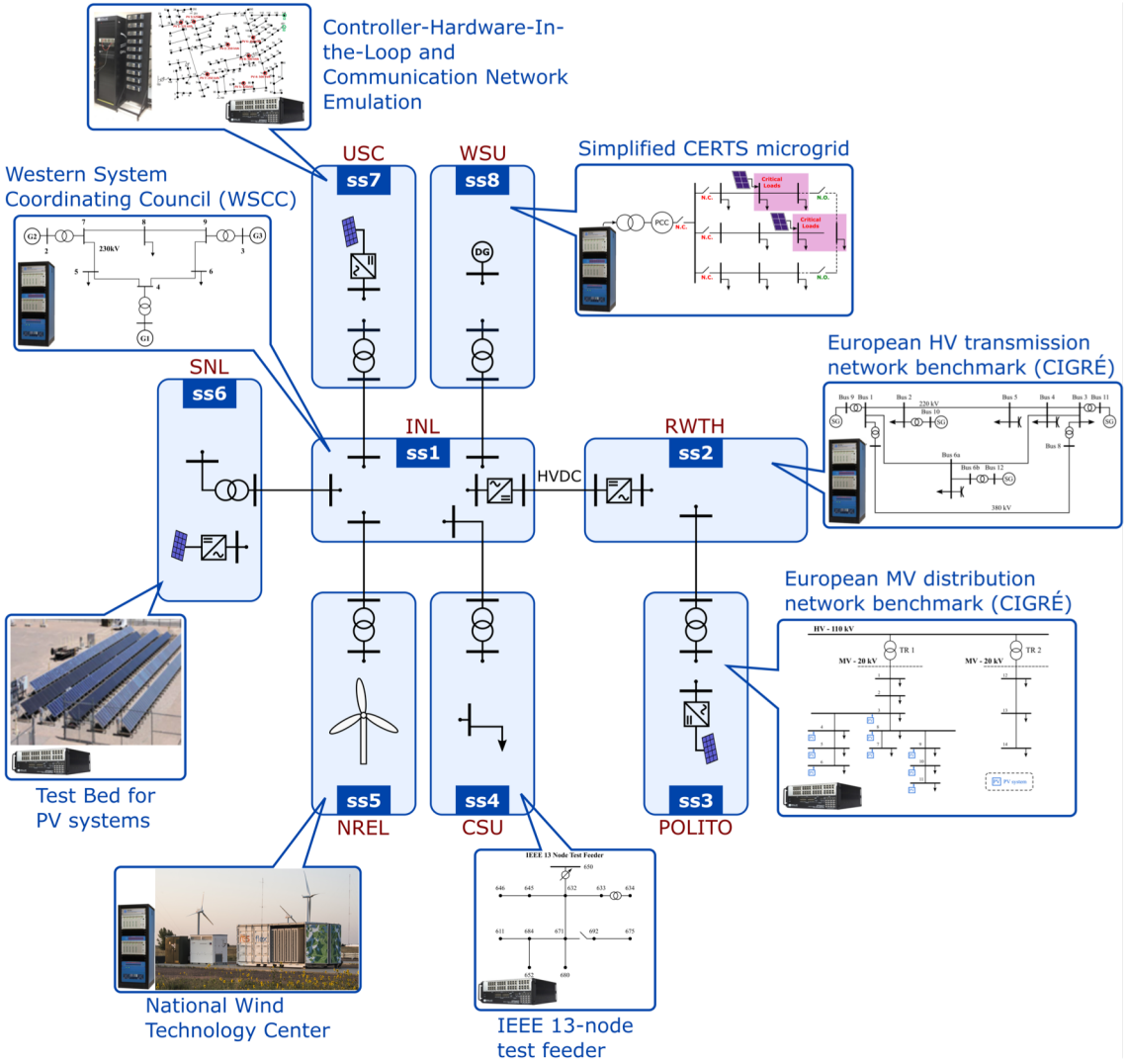
RT-Super Lab
Transatlantic Distributed Test Bed

Objectives

- Establish a vendor-neutral distributed platform based on interconnections Digital Real-Time Simulators (DRTS), Power-Hardware-In-the-Loop (PHIL) and Controller-Hardware-In-the-Loop (CHIL) assets hosted at geographically dispersed facilities
- Demonstration of multi-lab real-time simulation and distributed PHIL and CHIL setup for simulation and analysis of next generation global power grids



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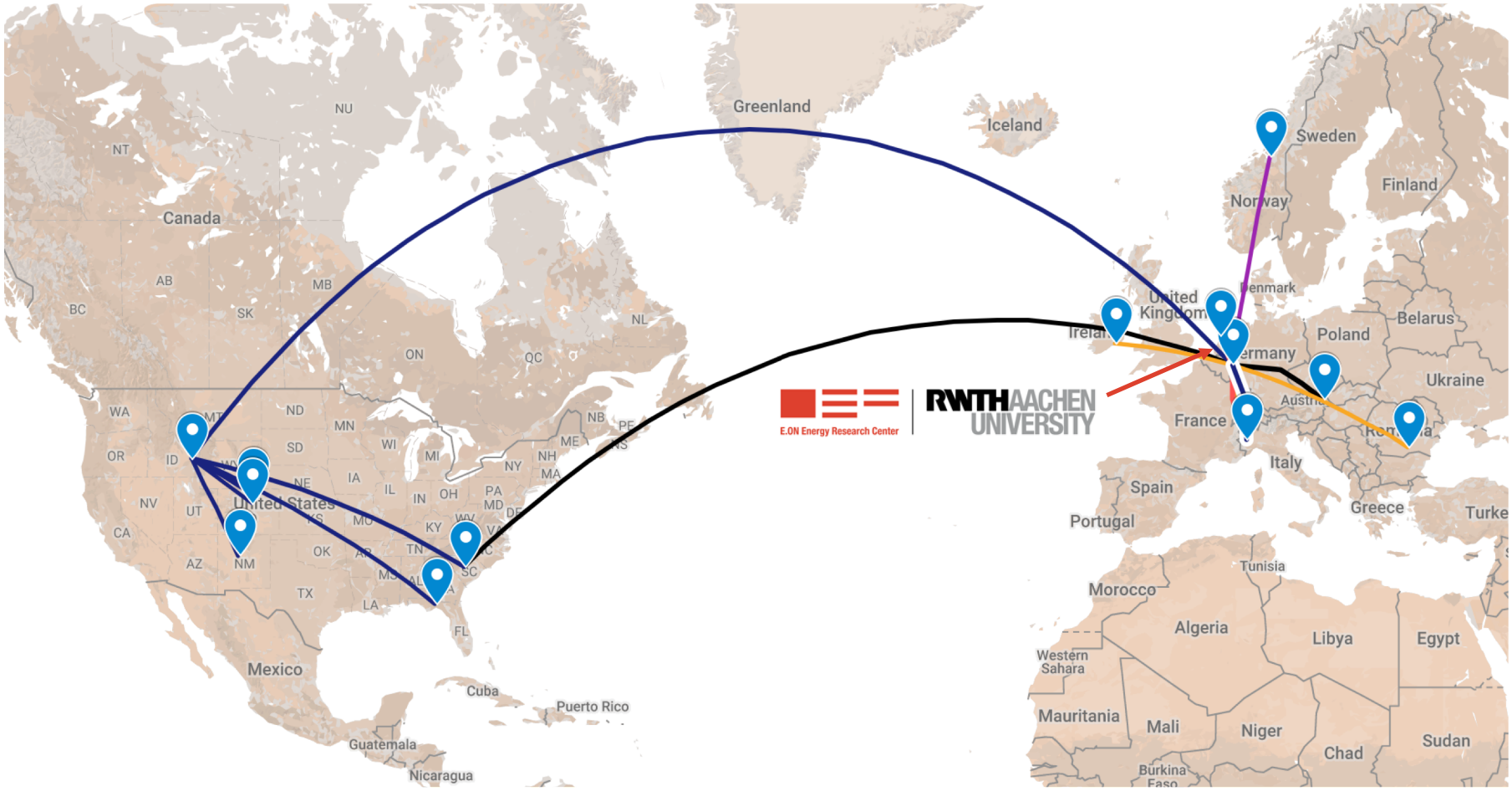
Existing deployments of RWTH VILLASframework



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