POLITECNICO DI TORINO

G-RTSLab

MULTI-MODELLING AT POLITO: MULTI-SITE PLATFORM FOR CO-SIMULATION OF POWER SYSTEMS

TU Delft, April 16th 2019

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OUTLINE

1. CONTEXT
2. REAL-TIME SIMULATION CONCEPTS
   - AN INTRO TO PARALLESIM IN RTS
   - DIFFERENT RTS FRAMEWORKS (SIL, HIL)
   - RTS ADDED VALUES FOR SMART GRIDS
   - DISTRIBUTED RTS (LOCAL AND MULTISITE)
3. LAB FACILITIES AT POLITO (DEPT. & EC-LAB)
4. SOME EXAMPLE OF USE CASES
5. MULTISITE REAL-TIME CO-SIMULATION

1 CONTEXT
ENERGY TRANSITION DRIVERS

The World and Europe in particular, are currently facing an Energy Transition that will substantially change the energy systems. The main goals and targets of this transformation are clear and some of the key drivers are here summarized:

- massive integration of renewable sources
- increasing accessibility to cheap and efficient ICT systems
- renovation of the wholesale and retail markets towards a EU wholesale energy market (Energy Union)
- Crucial and increasing role played by electricity in the energy sector
- active participation of end consumers/prosumers
- emerging role of storage
- new interaction paradigms for the transmission and distribution level.

ENERGY TRANSITION NEEDS

To drive this Energy Transition, we need science-based tools and research infrastructures to:

- Support the design and validation of rules (e.g. network codes),
- Support investment programs,
- Support new manufacturing processes and technologies,
- Foster new learning processes and strategies.

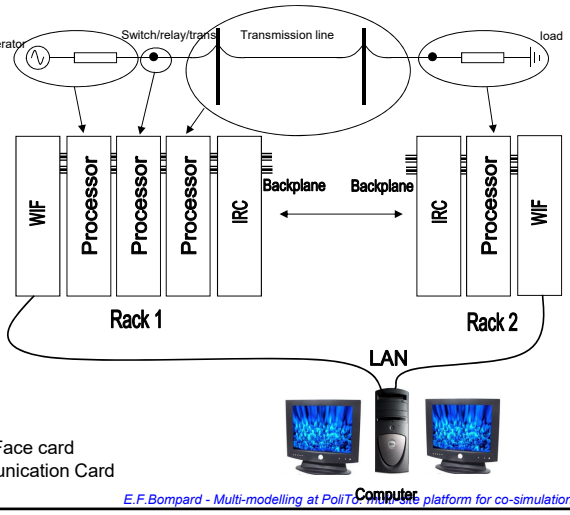
No single research facility can meet all needs and ambitions.

The process must be performed keeping the stakeholders linked to the activities so that the whole energy community moves together towards the final goal of a carbon free society.

PARALLELISM IN REAL-TIME SIMULATION

A real-time digital simulator performs parallel computation with multiple input/outputs allowing it to be connected to and control external hardware and equipment directly from the simulation.

Theses processors are different from ones which are used in offline parallel computing: they are programmed for specific tasks of RTS (programmed FPGA in Opal-RT, or programmed PB5 for RTDS).



WIF: Workstation InterFace card
IRC: Inter-Rack Communication Card

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FPG
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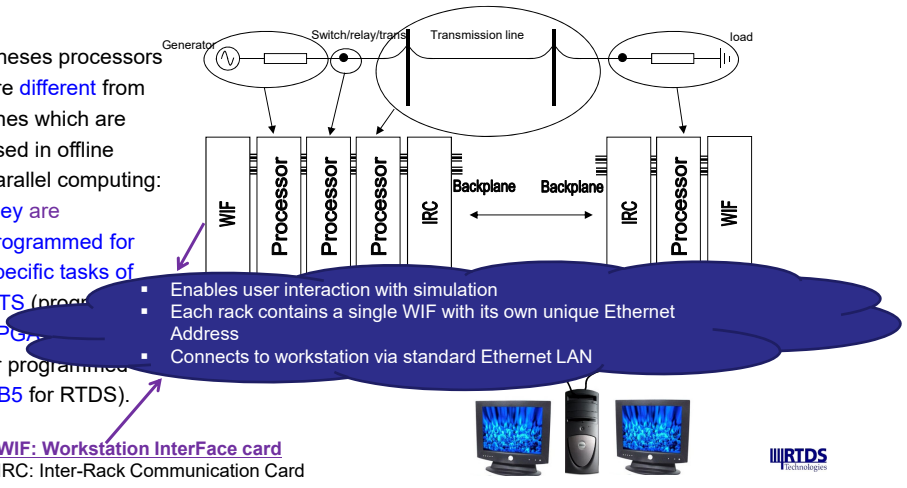
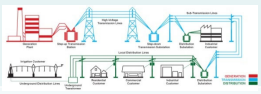
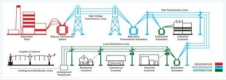
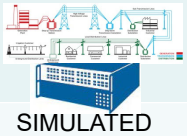
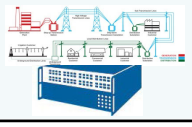


WIF: Workstation InterFace card
IRC: Inter-Rack Communication Card

REAL-TIME SIMULATION FRAMEWORK

TARGET	ENVIRONMENT	Type	Abb
REAL 	REAL 	**No Simulation** (REAL-LIFE)	R-L
SIMULATED 	REAL 	**Software In-The-Loop** (testing a virtual prototype – before manufacturing or a control strategy)	SIL
REAL 	SIMULATED 	**(Power) Hardware In-The-Loop** (testing manufactured product or control devices)	(P)HIL
SIMULATED 	SIMULATED 	**Pure Simulation**	P-S

REAL-TIME SIMULATION ADVANTAGES

- Possibility of replacing physical devices with virtual devices:
  - reduces costs
  - enabling more complete testing of the entire system
  - enables continuous testing:
    - without interruption
    - under possibly dangerous conditions
    - with many possible configurations without physically modification
- Possibility of testing even when you have no physical prototypes.
  - proceeding to test the device model before implementation (Software in-the-loop)
- Simulating a system realistically responding to its environment:
  - the inputs/outputs of the simulation are synchronous with the real world
  - when the simulation clock reaches a certain time in real-time simulation, the same amount of time has passed in the real world

REAL-TIME SIMULATION OF SMART GRIDS

Generally, to simulate smart grids, we need:

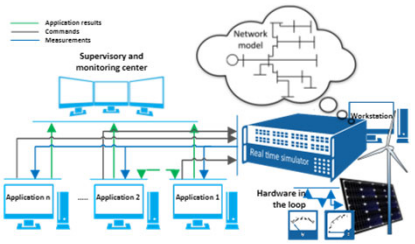
- Large-scale models with many emerging components (e.g. new controllers for Doubly Fed Induction Generators) distributed in different level of voltages (e.g. MV and LV distributed generations) with interoperability with other infrastructures (e.g. gas network) or layers (e.g. communication layer).
- High performance computing systems (HPC) as well as Hardware in-the-loop setups is needed to be coupled with the core simulation tool; and execution of models should be controlled in such a way that the dynamic behaviour of the real-world system would be emulated as much as possible.

Performing "real-time simulation" seems inevitable to meet all above-mentioned simulation requirements

DISTRIBUTED REAL-TIME SIMULATION

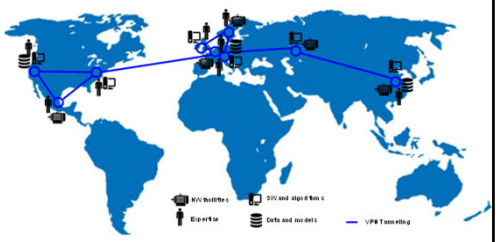
Local Distributed Co-Simulation

✓ Running a real-time co-simulation using local assets existing in a lab or campus.



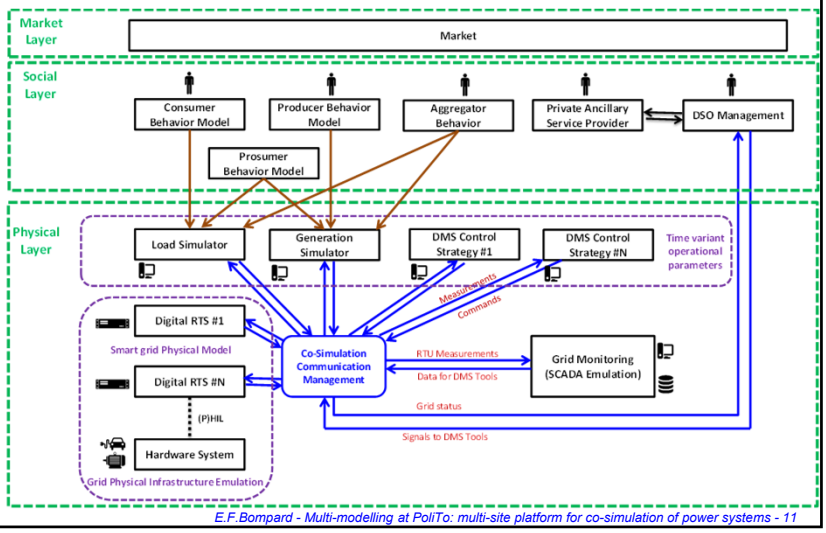
Multisite Co-Simulation

✓ Running a geographically distributed real-time co-simulation using distant assets existing in different cities, countries, or continents.



LOCAL DISTRIBUTED CO-SIMULATION

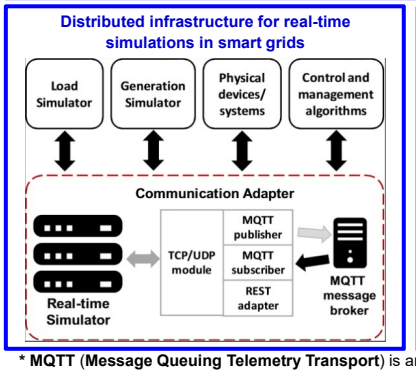
Integrating different simulation platforms or physical devices in a local laboratory to enable smart grid multidisciplinary and interoperability analysis, an example:

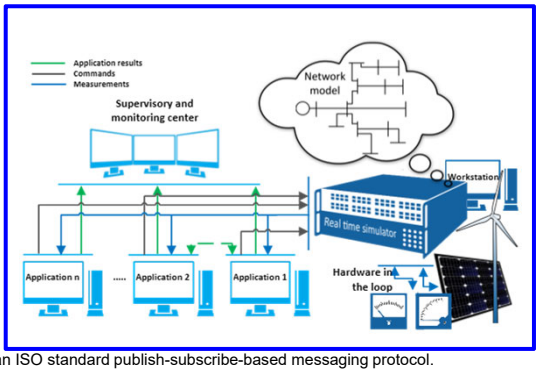


LOCAL DISTRIBUTED CO-SIMULATION @ POLITO

Different development nodes and simulation tools can access the RTS core lab through:

- An IoT MQTT*-based broker,
- A plug-and-play service system
- soft-sharing of expertise from different laboratories supporting interdepartmental collaborations in research.





* **MQTT** (**Message Queuing Telemetry Transport**) is an ISO standard publish-subscribe-based messaging protocol.

G-RTSLab @ EC-L Torino - Italy

G-RTS lab, is an internationally interconnected lab of real-time simulation. It is active in studying the role of electricity in energy transition, as well as new smart grids and super grids for electricity. HW (transformation devices, storage devices, RES, converters, etc.) and SW (control tools and strategies, market scenarios, optimization techniques, socio-economic impact, etc.) can be studied “in the loop” at a local scale with the possibility to scale-up the results on a global scale

LAB FACILITIES @ EC-L/POLITO (IN-PROGRESS)


Real time simulator

- **OP5600** HIL Box Real-Time Computer 3.46 GHz, 12 cores (Spartan 3 Platform)
- **eMEGAsim**
- **ePHASORsim** (Up to *2000* nodes)

APS series of 4-quadrant amplifiers

4-QUADRANT VOLTAGE / CURRENT AMPLIFIER

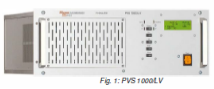
KEY FEATURES

- 6.75 – 160 kW
- 2 Quadrant Power Supply
- Regenerative up to 100% rated power
- 1 channel Output: 0 to 750V, 0 to ±555A
- 3 channels Output: 0 to 750V, 0 to ±185A/ch
- Constant Voltage, Static, and Dynamic modes

BE

Battery Emul

Photovoltaic Simulators
PVS and PVS/HV series
PVS 1000/LV
The High Speed Simulators



LAB FACILITIES @ EC-L/POLITO (IN-PROGRESS)

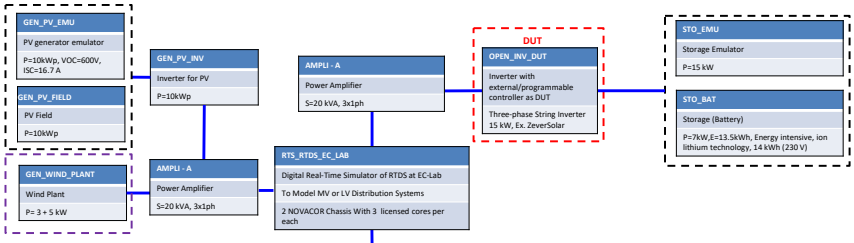
SIMULATORS

RTS OPAL	ePHASORsim configuration, 12 cores, complete of connection module
RTS OPAL	1 core, eMEGAsim + ePHASORsim, complete of connection module
RTS RTDS	1 NOVACOR Chassis With 4 licensed cores

SOME EXAMPLES OF USE CASES (1/4)

4

LOW INERTIA SYSTEMS



In a scenario of high penetration of RES (PV & Wind) the mechanical inertia of electricity systems is decreasing .

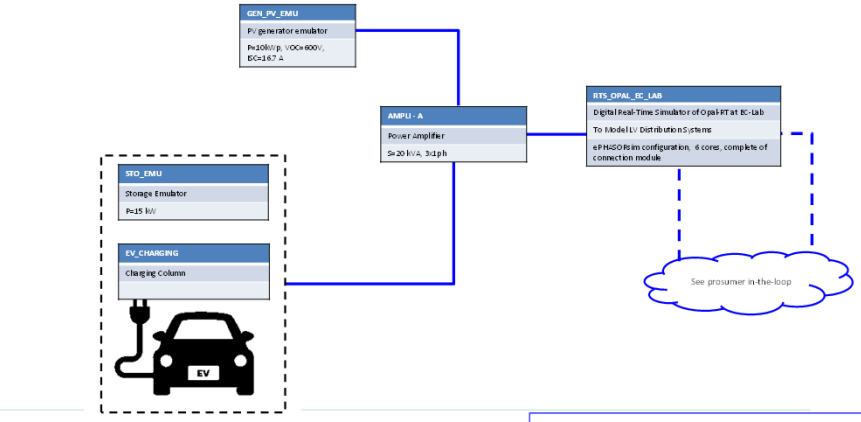
The test bed allows for the simulation of the control strategies of converters and electricity grid under different level of penetration of RES and for analyzing the interactions between synchronous machine and power converters with a PHIL approach.

Changing the level of inertia in grid and test how converters can face this new condition; possible interaction with synchronous machines

Device Under Test — Physical Connection — Data Connection — Alternatives

SOME EXAMPLES OF USE CASES (2/4)

VEHICLE TO GRID SYSTEMS



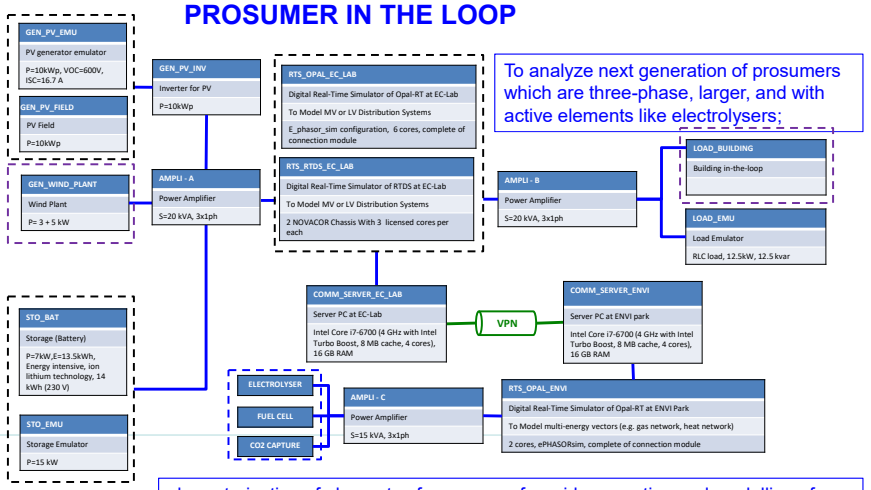
A real-time simulation platform to test control strategies for the management of the interaction between a smart grid and active prosumers will be designed.

Different strategies to control charging column of electric vehicles and distributed storage are examined to manage a realistic distribution network model.

Device Under Test — Physical Connection — Data Connection — Alternatives

SOME EXAMPLES OF USE CASES (3/4)

PROSUMER IN THE LOOP



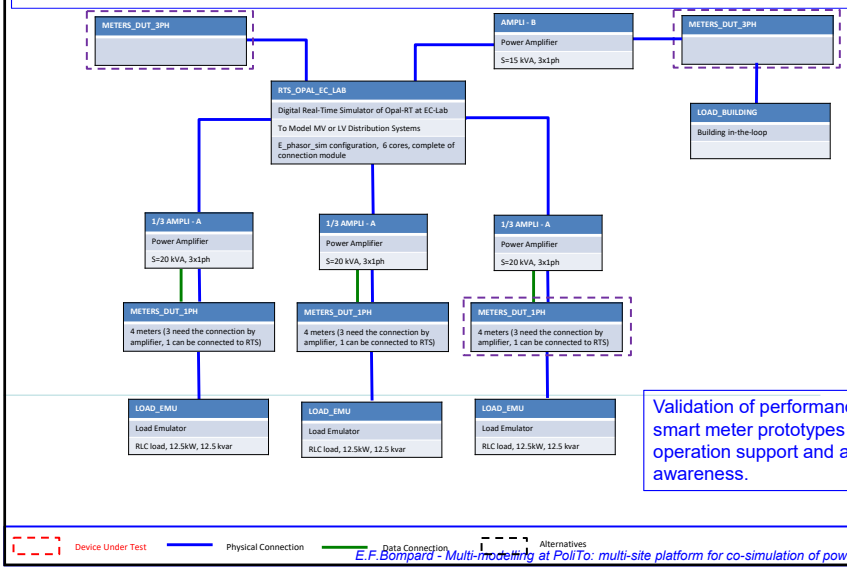
To analyze next generation of prosumers which are three-phase, larger, and with active elements like electrolysers;

characterization of elements of prosumers for grid connection and modelling of different types of renewable generation in this context are desired.

Device Under Test — Physical Connection — Data Connection — Alternatives

SOME EXAMPLES OF USE CASES (4/4)

SMART METER IN-THE-LOOP



Validation of performance of new smart meter prototypes for grid operation support and also user awareness.

A LAB EXPERIMENT: WIDE AREA MONITORING

Testing a new algorithm of **distribution state estimation to support wide area monitoring** system; this algorithm only needs measurement from primary substation and estimated data of PV production from a PV simulator;.

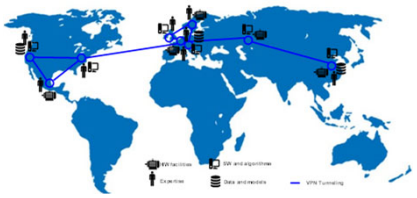
SET-UP

An OP5600 Opal-RT digital real time simulator to run the grid; a laptop PC to run a distribution state estimation algorithm, and three different desktop PCs to execute PVsim, to run the MQTT message broker and to accommodate data storage, respectively.

MULTISITE REAL-TIME CO-SIMULATION

5

- VISION
- IMPLEMENTATION
- ALREADY DEMONSTRATED CONCEPT
- ERIC-LAB
- GLOBAL RT-SUPER LAB
- JOINT RESEARCH CENTRE ON ENERGY TRANSITION, MODELING AND SIMULATION



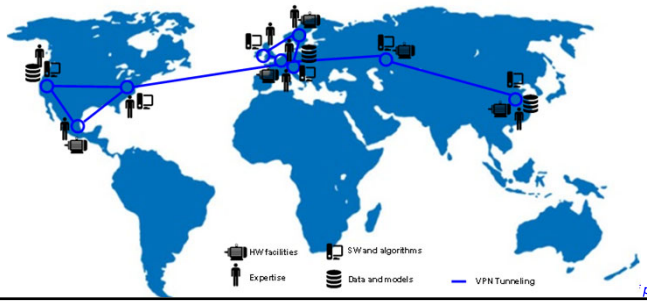
VISION: GLOBAL FEDERATION OF RESEARCH FACILITIES

VISION

A global federation of research facilities for supporting :
energy transformation based on an up-to-date ICT infrastructure with the support of local utilities and industry stakeholders.

GOAL

setting-up a federation of labs, located in different Countries, allowing for a cost-effective sharing of Knowledge, Data/Models, Hardware and Software facilities



IMPLEMENTATION: WHAT WE DO

WHAT

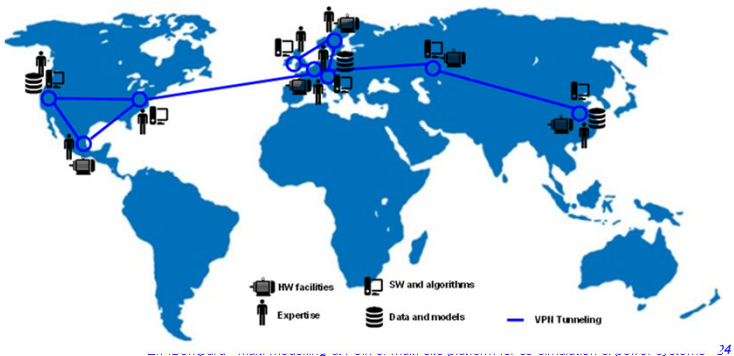
Global interconnection of electricity aims to allow sharing of renewable and non-renewable energy resources available among different countries and continents;

- Establishing this interconnection requires a lot of in advance studies and ex-ante verification of various proposals;
- But there are many components widespread in a large-scale system, and there is no integrated data/model;
- Similar to the widely dispersed real power system, its virtual model could be also built and executed in a multi-site distributed simulation platform;
- Interconnection of real-time co-simulation is a cost effective and technically feasible way to connect geographically distributed simulators and laboratory equipment.

IMPLEMENTATION : WHY IS IMPORTANT

WHY

- Enhancing simulation capabilities for large-scale systems
- Emulating physically distributed components
- Soft-sharing of HW/SW facilities
- Keeping susceptible data/model/algorithm confidential
- Soft-sharing of expertise



IMPLEMENTATION: HOW

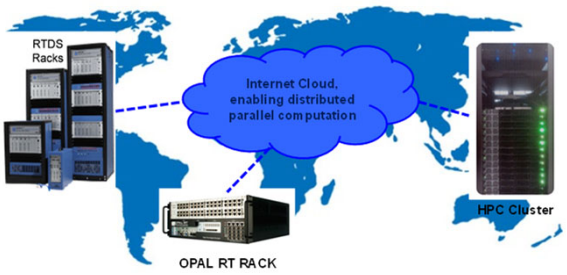
HOW

The infrastructure is based on integration of:

- Digital Real-Time Simulators (DRTS),
- High Performance Computing (HPC) systems,
- and (P)HIL setups and test beds

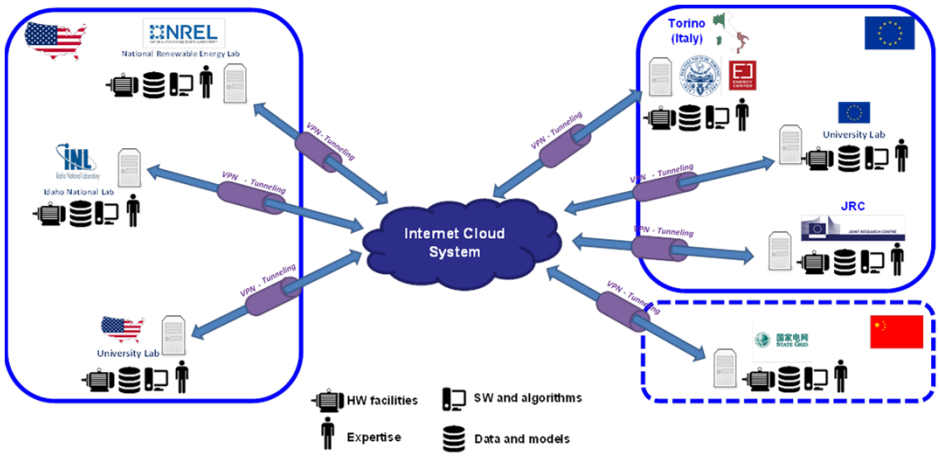
hosted at laboratories at different geographical locations.

A server-cloud architecture where the local computers or machines interact with other laboratories through VPNs.



LABS IN A NETWORK … NOT A NETWORK OF LABS

HOW



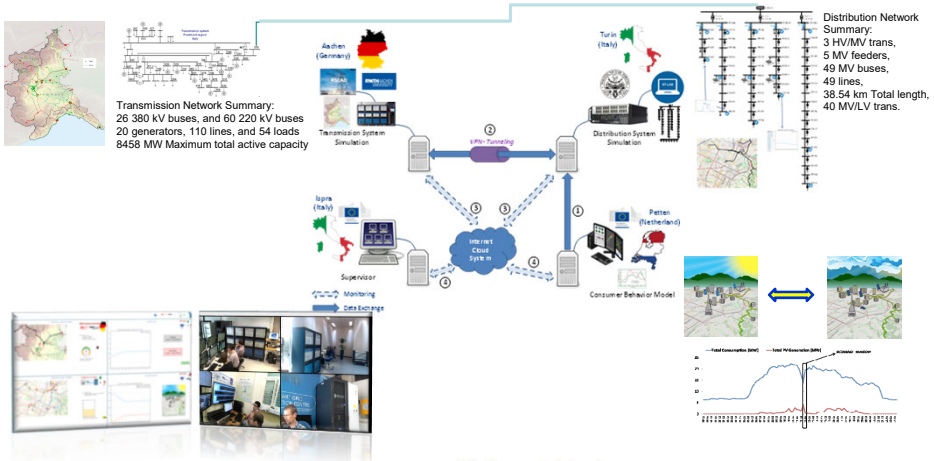
ALREADY DEMONSTRATED CONCEPT – ERIC-LAB CONCEPT

European Real-time Integrated Co-Simulation Lab ERIC-LAB

- A practical implementation of a federation of laboratories located in different European member states,
- Enabling a cost-effective sharing of hardware and software facilities with special focus on real-time simulation,
- Demonstration Setup Parties: Politecnico di Torino (Italy), RWTH-Aachen University (Germany), JRC-Petten (Netherlands), JRC-Ispra (Italy).
- Demonstration Simulation Case: Interplays of transmission and distribution systems (Piedmont/Turin) with high PV and EV penetration

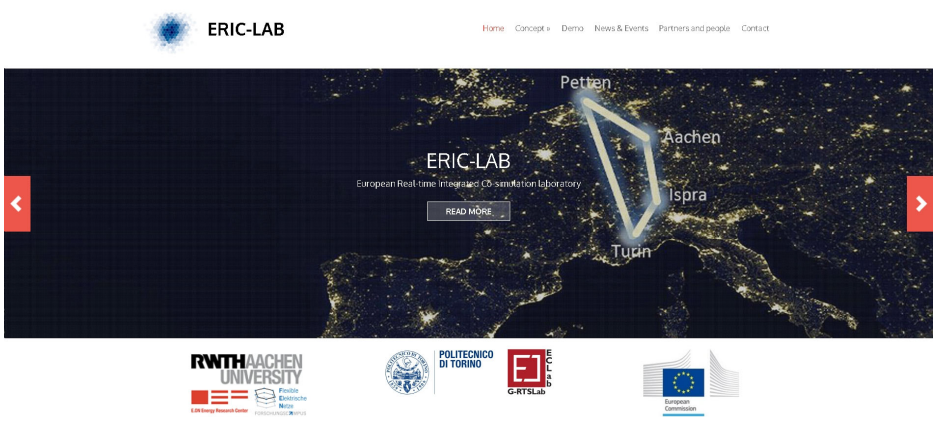
ALREADY DEMONSTRATED CONCEPT ERIC-LAB DEMO

Presented in the inauguration of the European Interoperability Centre for Electric Vehicles and Smart Grids of at JRC Ispra, on **Oct. 29th 2015** to Maroš Šefčovič (Vice President of the European Commission for Energy Union), Vladimir Sucha (General Director DG Joint Research Center of the European Commission), John Mac Williams (Associate Deputy Secretary of US Department of Energy).



http://www.eric-lab.eu/

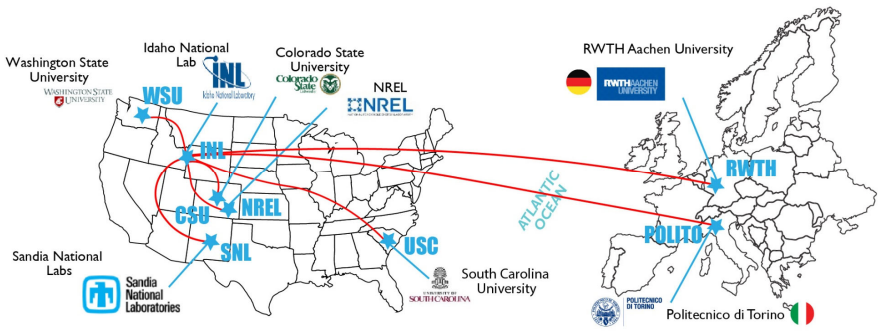
ALREADY DEMONSTRATED CONCEPT ERIC-LAB REFERENCE



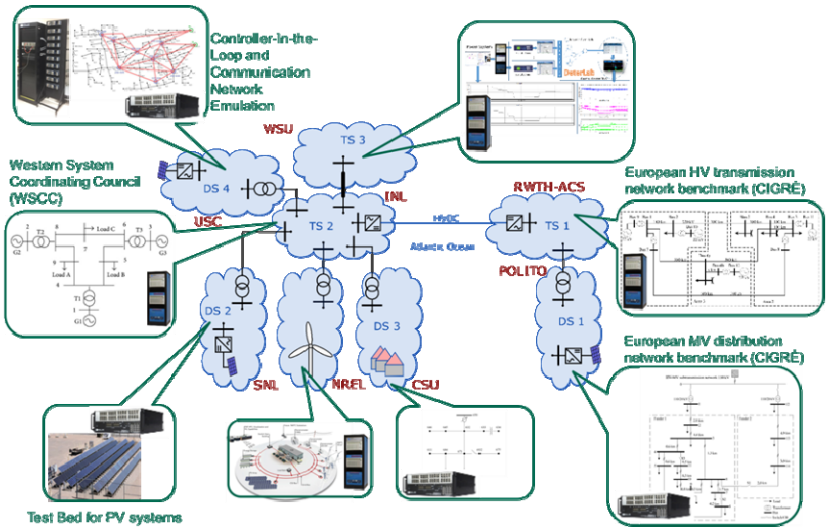
www.eric-lab.eu

GLOBAL RT-SUPER LAB

Global RT-Super lab demo is aimed to conceptually and technically prove feasibility of multi-site co-simulation across the Atlantic Ocean, and demonstrate potential and advantages of a holistic research approach enabled by a "laboratory in a network" through interconnecting EU-US laboratories and collaboration between research institutions.



GLOBAL RT-SUPER LAB - DEMO

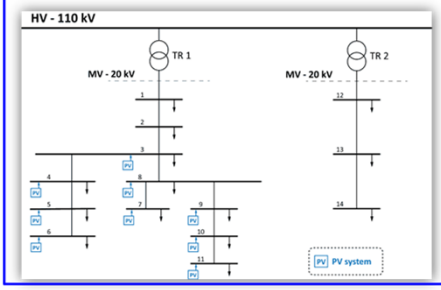


GLOBAL RT-SUPER LAB – DEMO – USE CASE @ POLITO

CASE: CIGRE Medium Voltage Distribution Network Benchmark – European Configuration

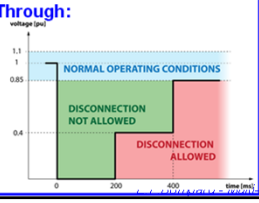
14 buses, 2 feeders, 46 MVA contractual load

Different PV penetration levels: 6 % and 20 %



Low Voltage Ride-Through:

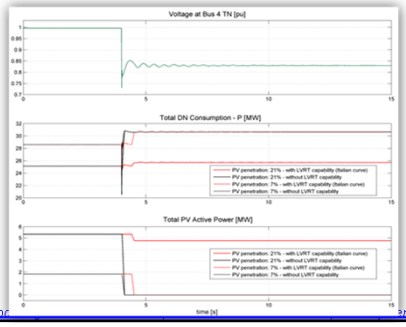
PV power plants with a rated power ≥ 6 kW cannot disconnect immediately after a voltage drop:



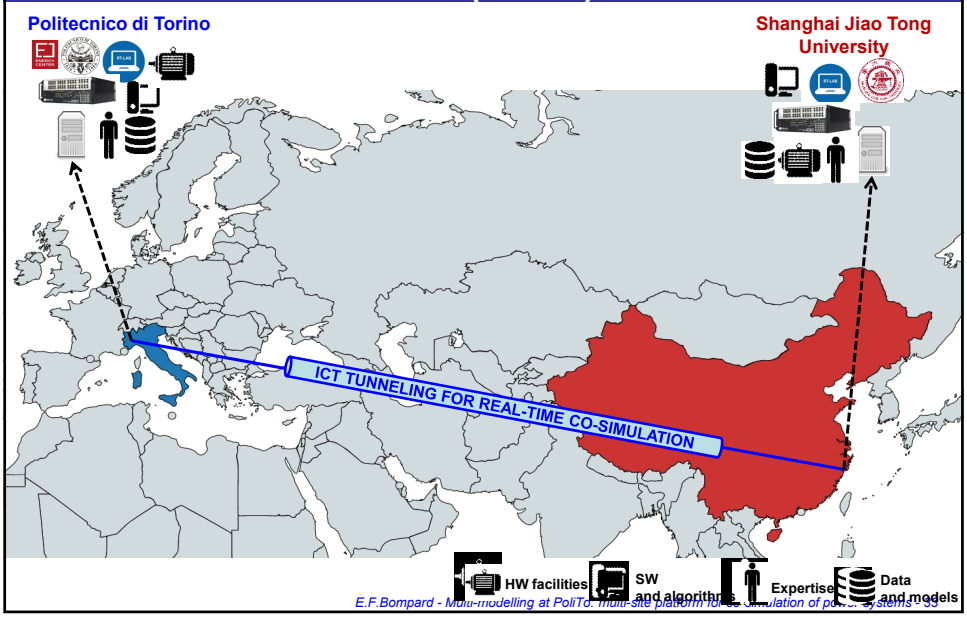
Capability assessment of distributed generation units (e.g. PV units) to remain connected to the distribution grid during faults on transmission grid

Remark: Transmission-distribution (TS-DS) interactions imply the need to do co-simulations

Scenario: disconnection of one conventional generator in TS results in voltage disturbances in DS



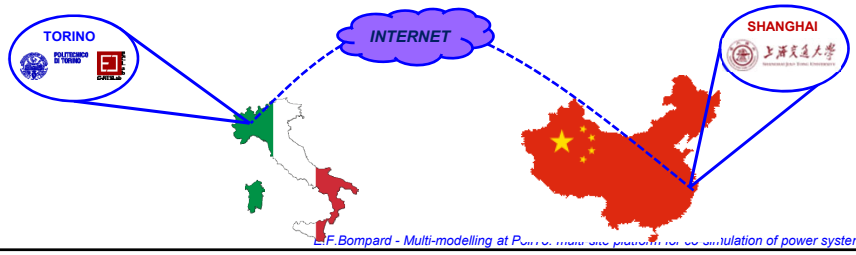
JOINT RESEARCH CENTRE ON ENERGY TRANSITION, MODELING AND SIMULATION (ETMS)



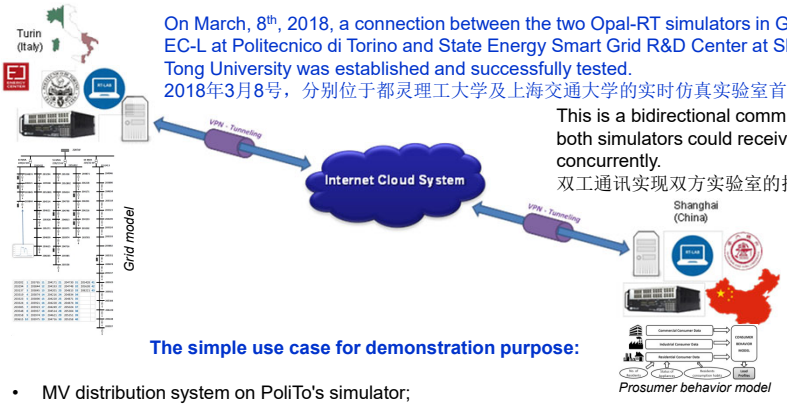
POLITO-SJTU JOINT LABORATORY ETSM

WHAT

- The lab is focused on actions on clean electricity towards energy transition;
- It brings up Belt and Road Initiative (BRI) in global interconnection;
- It is a brand new concept to make people from distant locations and different expertise work together;
- It fosters common understanding based on a two-node interconnected lab facilities in Turin, Italy and Shanghai, China;



EU-CHINA FIRST MULTISITE REAL-TIME SIMULATION



On March, 8th, 2018, a connection between the two Opal-RT simulators in G-RTSLab of EC-L at Politecnico di Torino and State Energy Smart Grid R&D Center at Shanghai Jiao Tong University was established and successfully tested.
2018年3月8号，分别位于都灵理工大学及上海交通大学的实时仿真实验室首次实时连接成功

This is a bidirectional communication and both simulators could receive data concurrently.
双工通讯实现双方实验室的持续信号收发

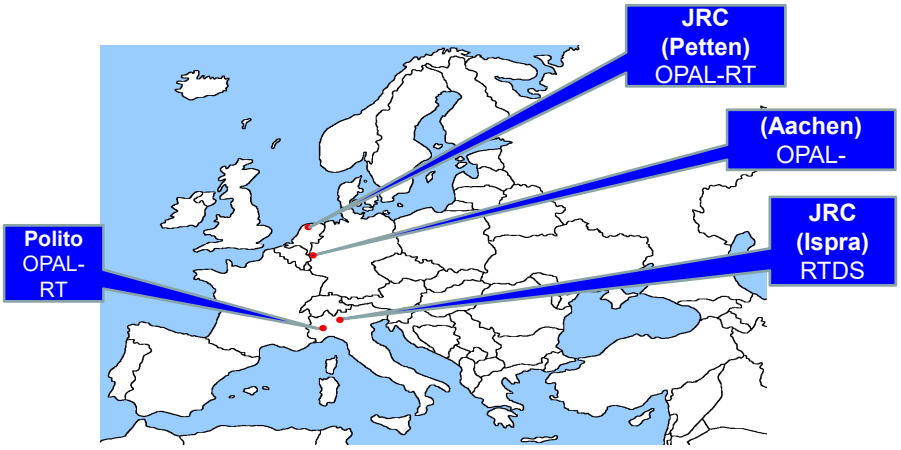
The simple use case for demonstration purpose:

- MV distribution system on PoliTo's simulator;
- Prosumer behavior model on SJTU's simulator;
- PoliTo's simulator sends voltage and current measurements, while SJTU's simulator sends a set of P, Q values for all substations to PoliTo;
- Communication report time equal to 5 seconds to stress latency and reliability of the connection;
- Successful Stress test also with 1 second rate;
- Both models run with 250 microsecond time-step in EMT using eMEGAsim configuration.

SIMULATION OF THE ENERGY DIMENSION OF THE BRI

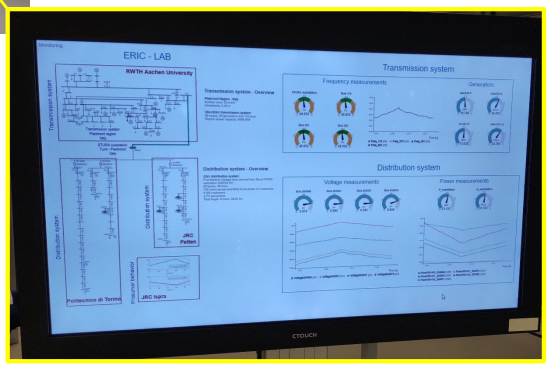
ERIC-LAB DEMO IN NOVEMBER 2018

- Presented in the inauguration of smart grid center at JRC-Petten in the Netherlands



JRC SG LAB IN PETTEN (NL) OPENING CERIMONY - ERIC-LAB (NOV18)

- A portion of Turin distribution grid is modeled in Opal-RT in Turin, another portion of Turin distribution grid is modeled in Opal-RT in Petten;



- Piemonte transmission system supplying Turin distribution network, is modeled in Aachen;
- Load and generation scenarios are controlled in Ispra.a

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