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POSYTYF

Le concept de la centrale virtuelle dynamique (DVPP) pour optimiser l'intégration des renouvelables au réseau

- résultats du projet H2020 POSYTYF –

Bogdan MARINESCU, Ecole Centrale Nantes
Coordinateur RIA H2020 POSYTYF

JOURNÉES SCIENTIFIQUES de l'Éolien

CENTRALE NANTES

LS2N

Content

- Short description of the POSYTYF topic
- The Dynamic Virtual Power Plant (DVPP) concept
- DVPP realization via controls
- Main outputs of the project
- Zooms on few (3) thematics

POSYTYF

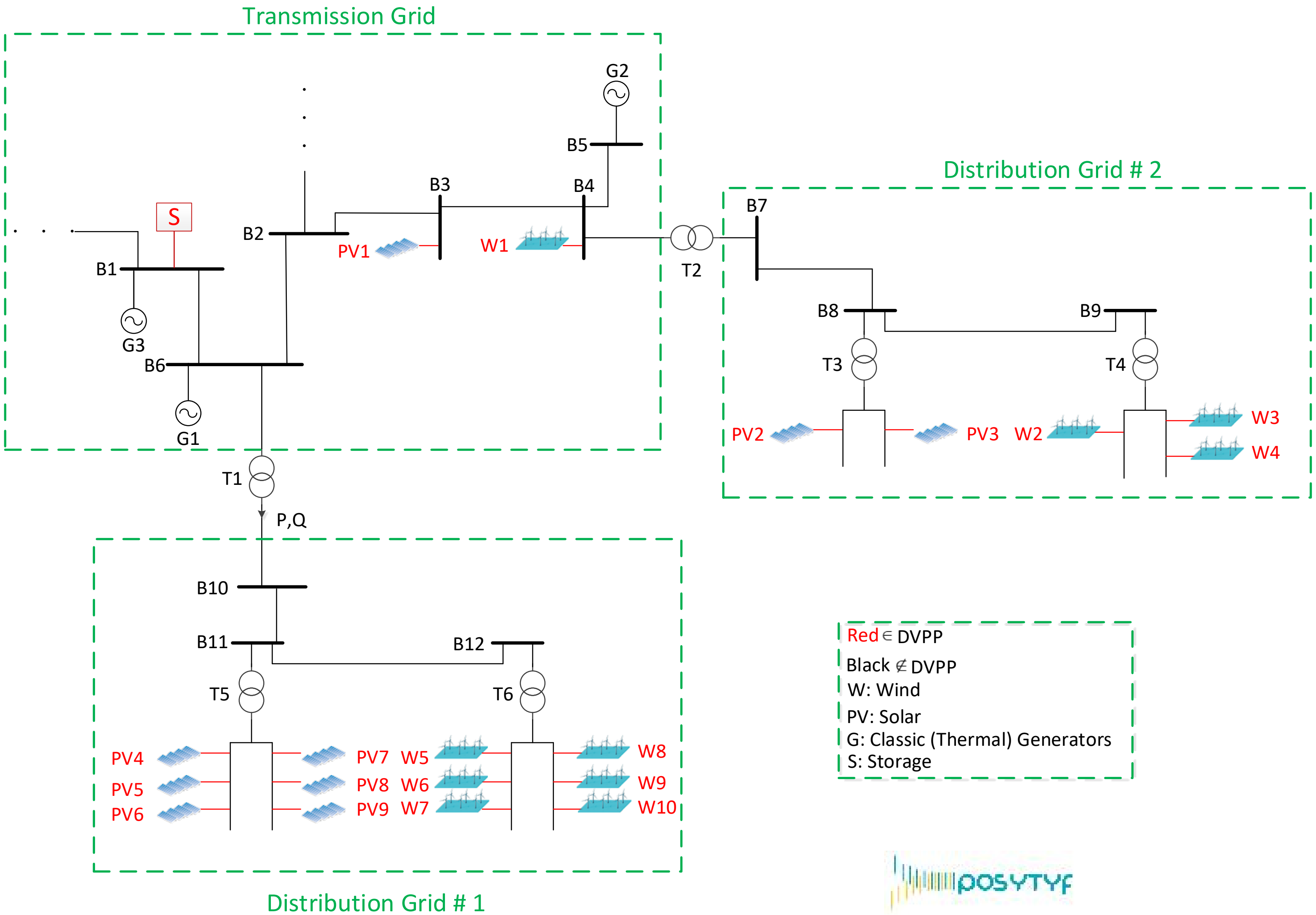
POSYTYF Project: POwering SYstem flexibiliTY in the Future through RES
Call: LC-SC3-RES-16-2019- Development of solutions based on renewable sources that provide flexibility to the energy system
Duration: June 2020 – May 2024
Budget: 4,7 M€
Coordinator: Ecole Centrale Nantes, France

Context:

- System stability is the main bottleneck to the further integration of Renewable Energy Sources (RES) into the power system.
- Distributed RES, if aggregated and technically/economically optimized, have the potential to provide flexibility to the grid and contribute to system stability.
- Dispatchable RES can beneficially complement non-dispatchable RES for such optimization ; alternative to electrochemical storage

Dynamic Virtual Power Plant (DVPP): a set of RES generators and control and operation methodologies to

- increase the performance of an integrated portfolio of **dispatchable** and **non dispatchable** RES
- operate together as a **virtual generator**, capable of providing flexibility and ancillary services to the energy system.



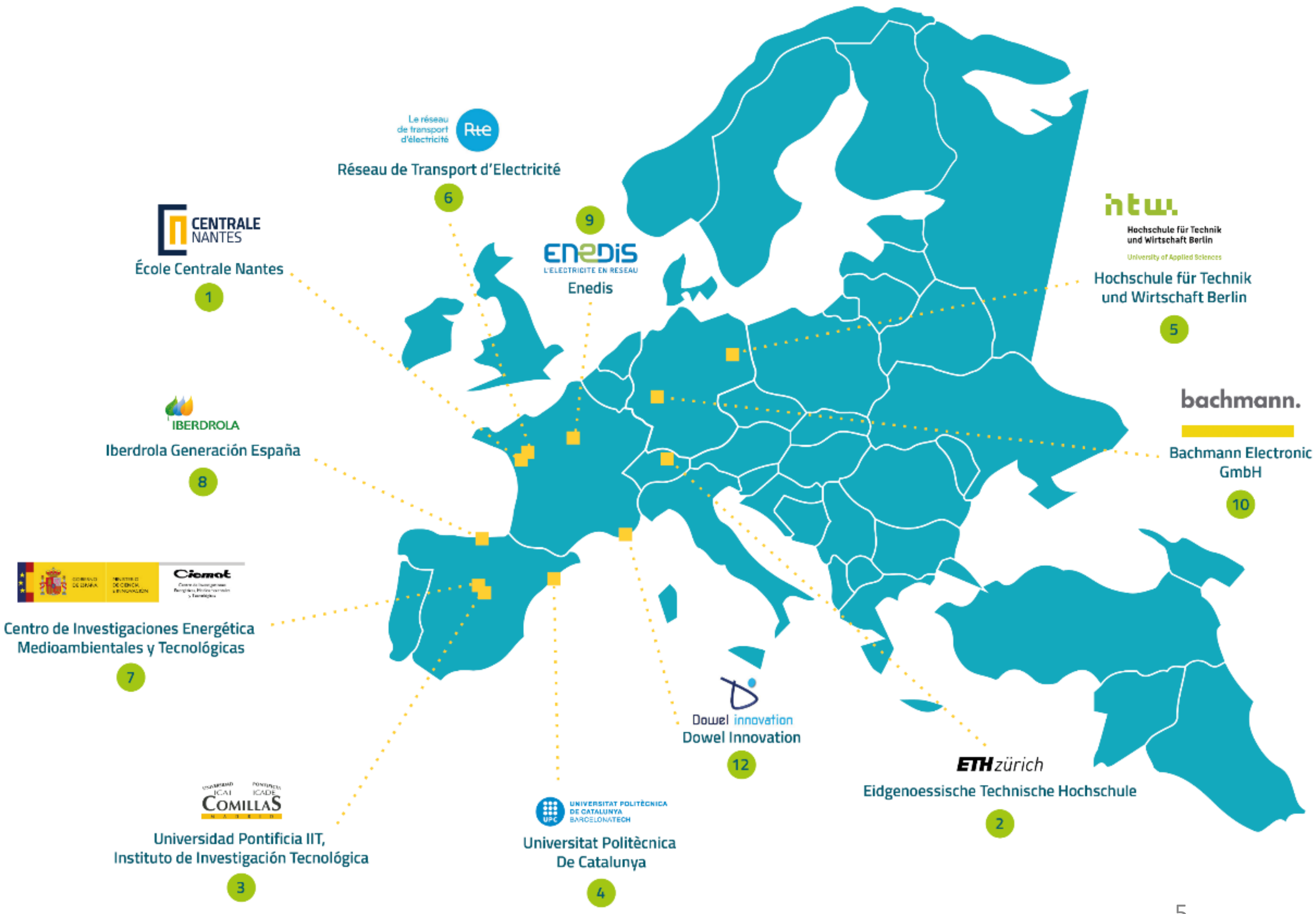
Red ∈ DVPP
Black ∉ DVPP
W: Wind
PV: Solar
G: Classic (Thermal) Generators
S: Storage

DVPP specificities:

- Both static and **dynamic** aspects + optimality
- Both local and grid objectives
- All time scales (fast V & f regulation + secondary control and markets integration)
- Multiple grid connections
- Transmission & distribution grids
- Imbricated structure
  (participating & non participating generators)
- Dynamic interactions
  - Between DVPP RES generators
  - With the neighbor dynamic elements
- Resilience/plug&play capabilities

Consortium

- Combined expertise on power systems, power electronics, automatic control and RES
- Industrial partners include (Transmission System Operators) TSO, (Distribution System Operators) DSO, RES generator, software vendor
- External advisors:
  - Prof. Costas Vournas, NTUA, Athens-Greece
  - WindEurope
  - ESTELA



Differences with existing Virtual Power Plants (VPP)

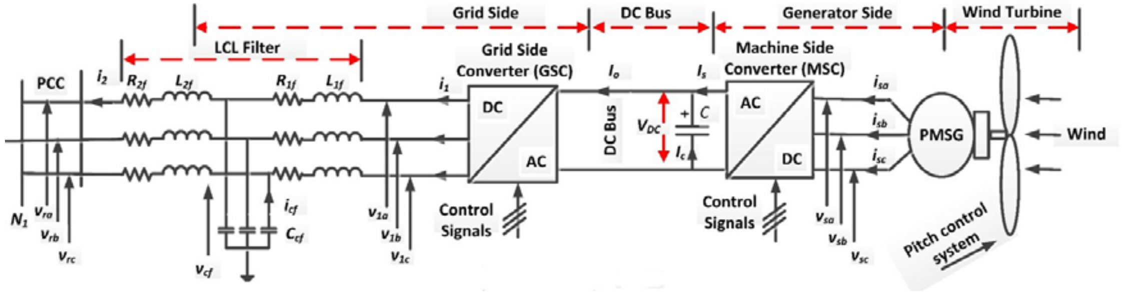
*Address both **static** & **dynamic** optimal control at **all** levels: device / network/ economic standpoint*

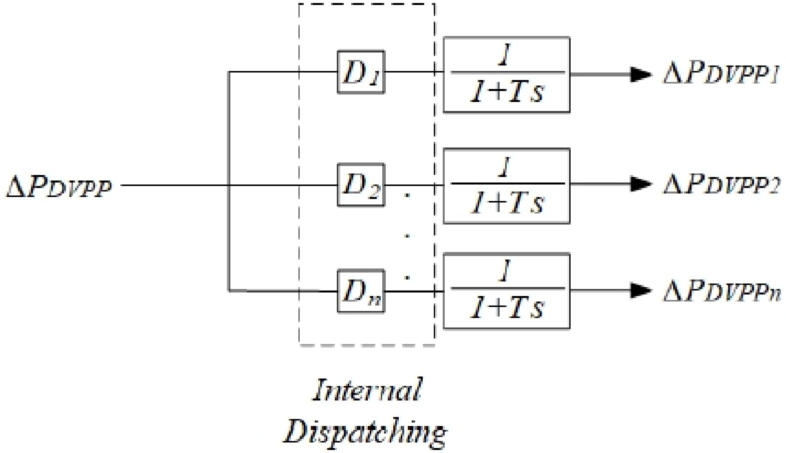
In more specific technical terms:

- Enable participation of distributed RES to ancillary services
- Manage specificities of decreasing global inertia of the system
- Deal with geographical spread of RES (also imbricated with non-participating entities)
    - Coordination/ centralization/ decentralization
    - Robustness/ disturbance rejection
    - Resilience (variable VPP perimeter)
- Aggregate RES at both transmission and distribution levels

DVPP realization: multi-time-scale dynamic system

objectives & actuators





Main outputs

- Key in hands solutions for renewables modeling, control & operation in both situations:
  - Scenario A: integration in existing grids and control schemes: primary and secondary levels
  - Scenario B: power systems of future with high (100%) power electronics rate
- novel stability notion for Scenario B
  - Definition of complex-frequency synchronization to analyze phase-magnitude coupled dynamics
  - Stability analysis of complex-frequency synchronization and voltage stabilization
  - control of multivariable DVPPs based on these notions
- real-time operation for whole time scales (fast to slow dynamics)
  - fast V & f regulation + secondary control and markets integration + internal redispatchig + cost optimization

More specifically

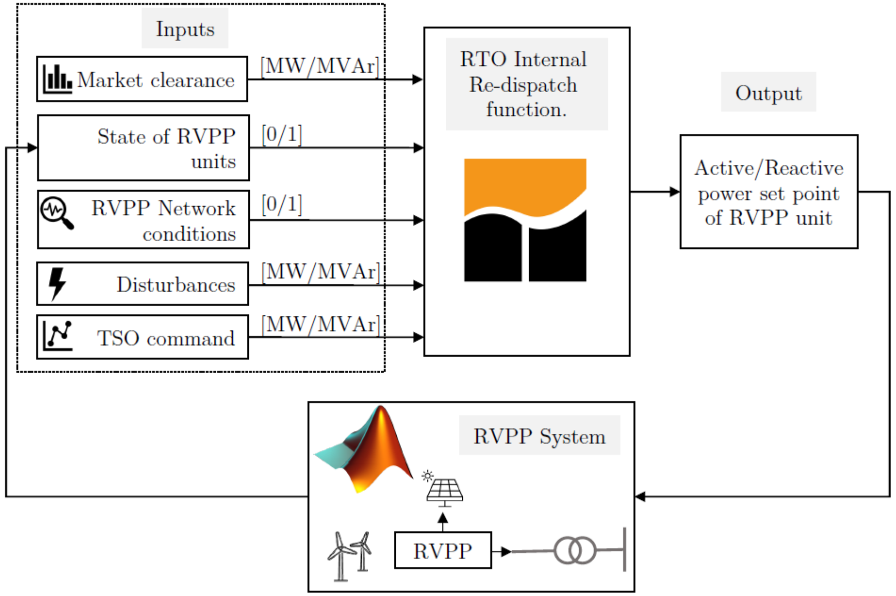
- Modeling
  - Definition of scenarios for modern power systems based on renewables
  - Analysis of potential grid services to be provided by dynamic virtual power plants
  - Modeling in RMS and EMT of modern power systems

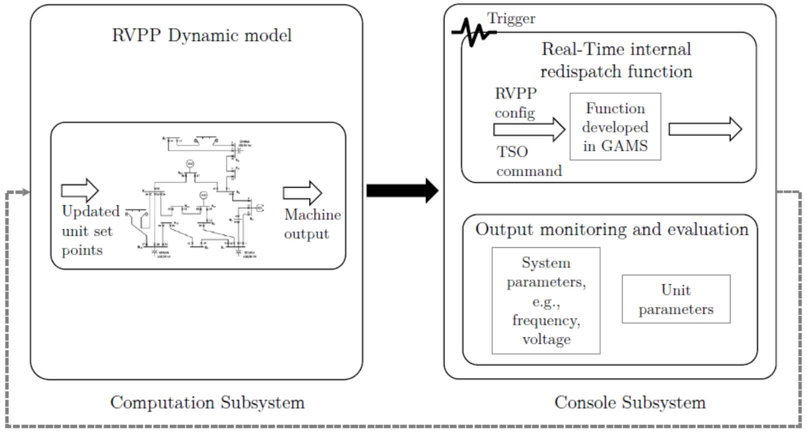
- Control
  - New model-based approach for the control of power electronics connected to the grid
  - Observer-based control
  - Decentralized control for DVPP actuators for both local & grid ancillary services
    - Centralized synthesis with overlapping implementation
    - Model matching with dynamic participation factors
  - Grid following/grid forming
  - Real-time simulation and hardware in the loop validations

- Optimization
  - Tool for the optimal operation of DVPPs under uncertainty of non-dispatchable RES
  - Tool for optimal real-time operation of DVPP portfolio
  - Analysis of economic viability of DVPPs and their impact on system operation and ancillary service needs ; competitiveness compared with solutions combining variable renewable sources with electrochemical storage.

Zoom: optimal real-time operation of DVPP portfolio

IIT Comillas Madrid





OPAL-RT real-time simulation: IIT Madrid-EC Nantes

GAMS optimization

$$\min_{\Xi^{\mathrm{RTO}}} \sum_{t\in\mathcal{T}} \Bigg[\sum_{k\in\mathcal{K}} \Big(C_k p_{k,t} + C_k^{\uparrow} p_{k,t}^{\uparrow} + C_k^{\downarrow} p_{k,t}^{\downarrow} + \lambda\big(p_{k,t}^{\uparrow} + p_{k,t}^{\downarrow}\big)\Big) + \sum_{b\in\mathcal{B}^{\mathrm{g}}} \Big(C_b^{\uparrow} p_{b,t}^{\uparrow} + C_b^{\downarrow} p_{b,t}^{\downarrow} \Big) \Bigg] \Delta t$$

Indexes and Sets

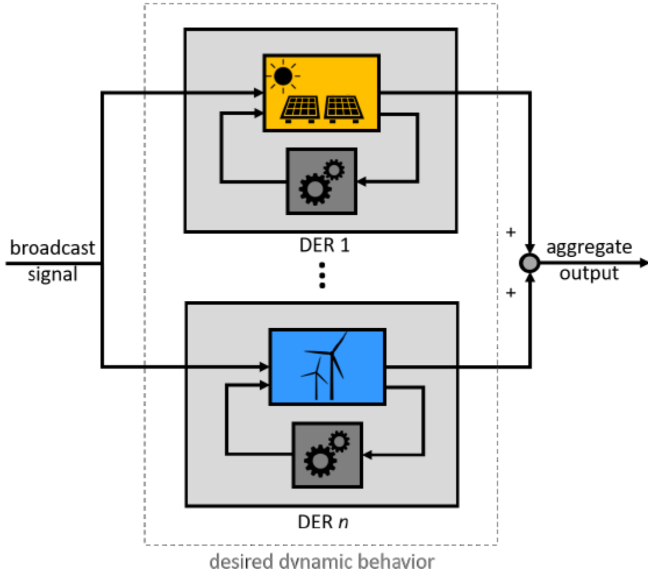
$b \in \mathcal{B}/\mathcal{B}^m$	Network Buses / Buses Connected to main grid
$k \in \mathcal{K}/\mathcal{K}_b$	RVPP units / RVPP units at buses
$(m,n) \in \ell$	Sending- and Receiving-end of line
$t \in \mathcal{T}$	Time periods

Variables

$p_{b,t}^{\mathrm{TSO}}$	Share of regulation to be delivered at bus b	[MW]
$p_{k,t}$	Active real time power generation of RVPP k	[MW]
$p_{k,t}^{\uparrow}$ ($p_{k,t}^{\downarrow}$)	Active power up(down) regulation of RVPP k	[MW]
$p_{mn,t}$	Active power flow from bus m to n	[MW]
$p_{b,t}^{\uparrow}$ ($p_{b,t}^{\downarrow}$)	Unmet up (down) regulation at bus b	[MW]

Zoom: primary control

- Centralized vs decentralized control



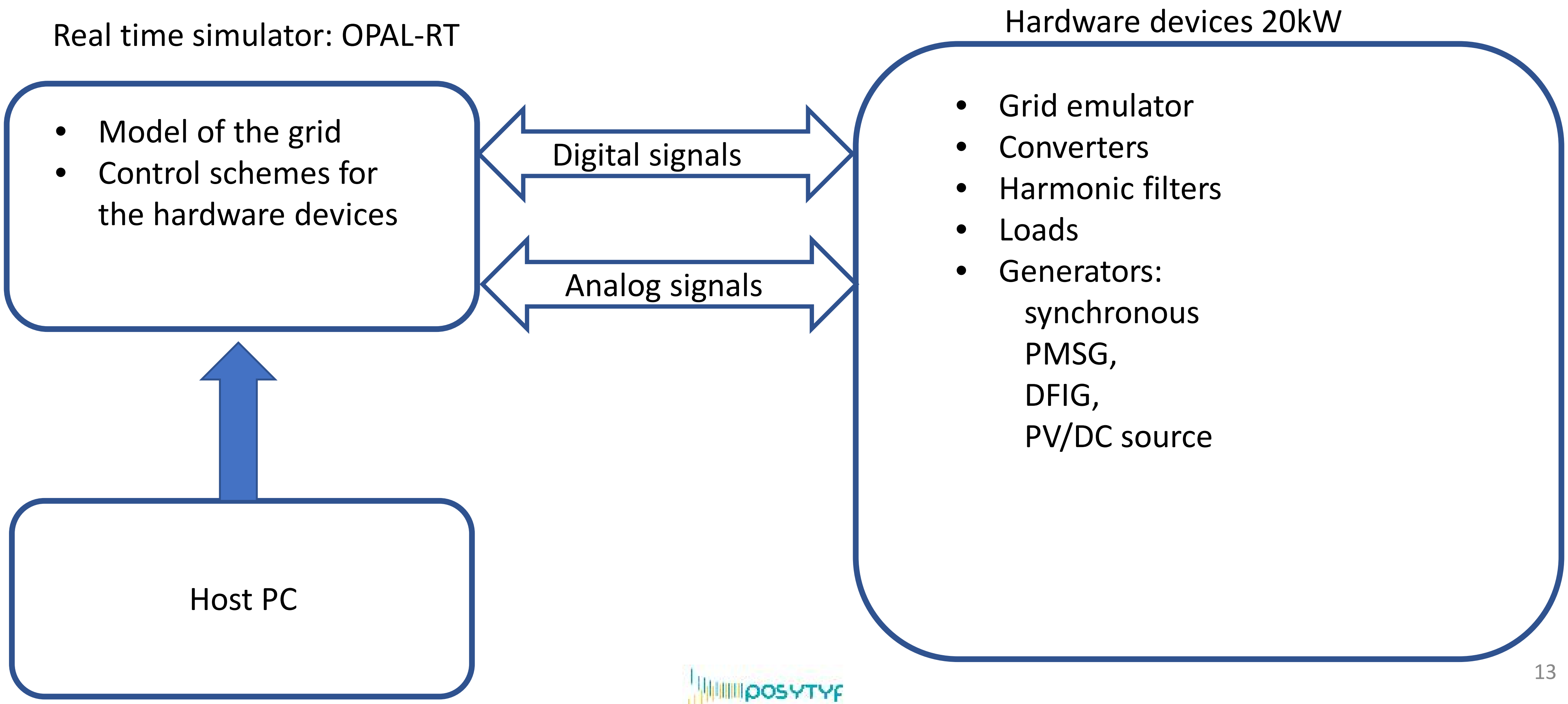
Zoom: decentralized controls

- Centralized synthesis with decentralized implementation: EC Nantes
- Fully decentralized: based on model-matching:

  ETH Zurich

Zoom: hardware validations

- Hardware 10kw bench in HTW Berlin: microgrid
- Hardware in the loop 20kw platform in EC Nantes-LS2N: Full hardware grid connected chain & grid emulation



Real time simulator: OPAL-RT

- Model of the grid
- Control schemes for the hardware devices

Digital signals

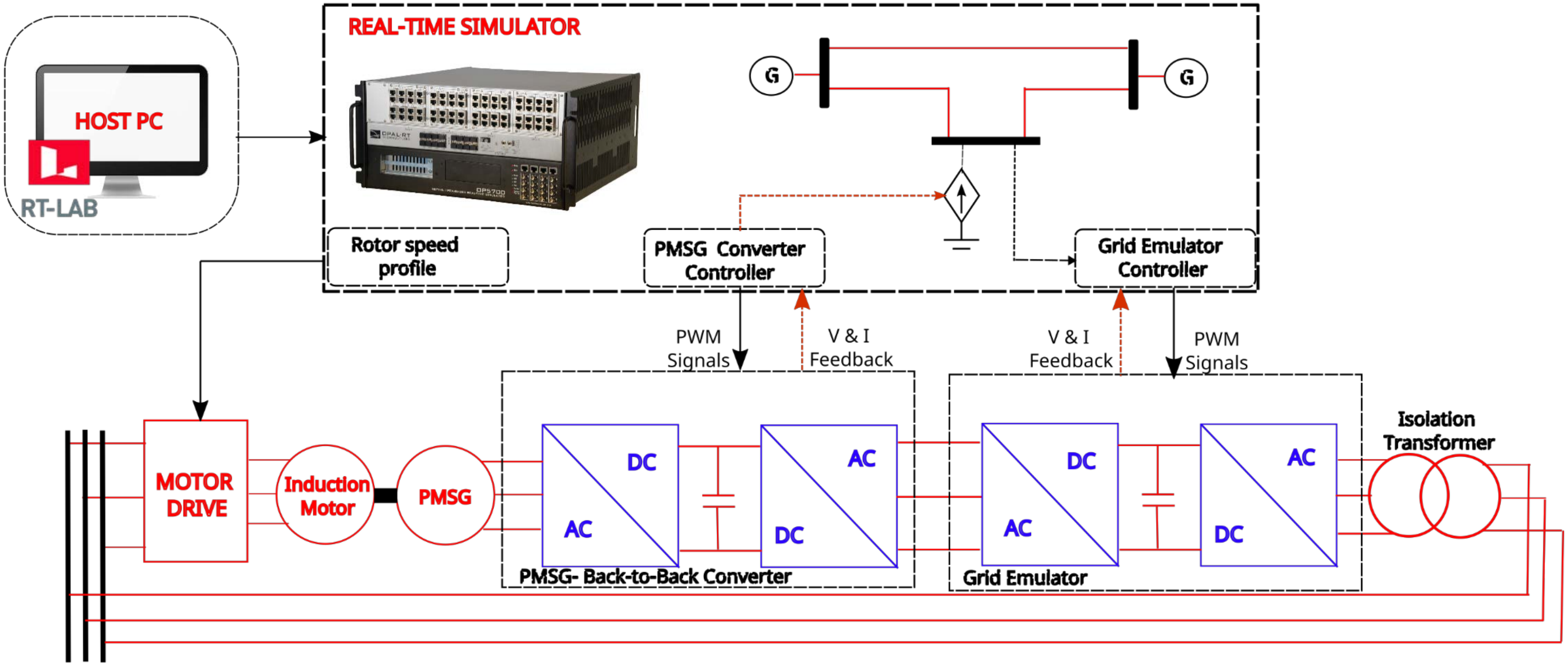
Analog signals

Host PC

Hardware devices 20kW

- Grid emulator
- Converters
- Harmonic filters
- Loads
- Generators:
  synchronous
  PMSG,
  DFIG,
  PV/DC source

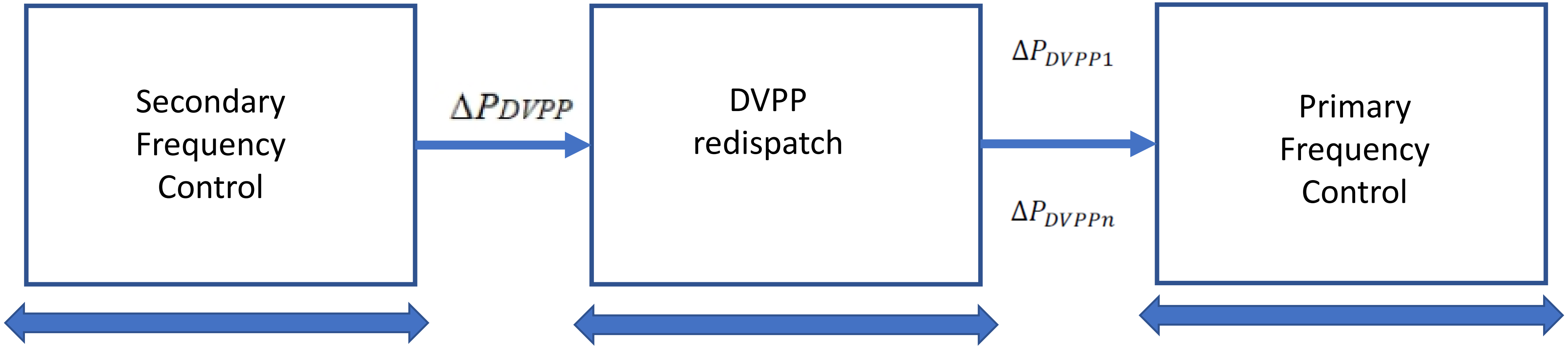
Permanent Magnet Synchronous Generator(PMSG)- Test Bench




OPAL-RT TECHNOLOGIES

Validations at sevreal time and grid scales

- Local fast control for grid V & f services
- Primary/internal redispatch/secondary controls: OPAL-RT/GAMS interface



Secondary Frequency Control

ΔP_{DVPP}

DVPP redispatch

ΔP_{DVPP1}

ΔP_{DVPPn}

Primary Frequency Control