DEVELOPMENT OF A CO-SIMULATION TEST BENCH FOR POWER SYSTEM STUDIES WITH HIL AND PHIL

TIMO WAGNER, CHRISTIAN SCHEIBE, GERT MEHLMANN (FAU-LEES)

MORITZ WEBER, MICHAEL KYESSWA, UWE KÜHNAPFEL (KIT-IAI)

FELIX WEGE (RWTH-ACS)

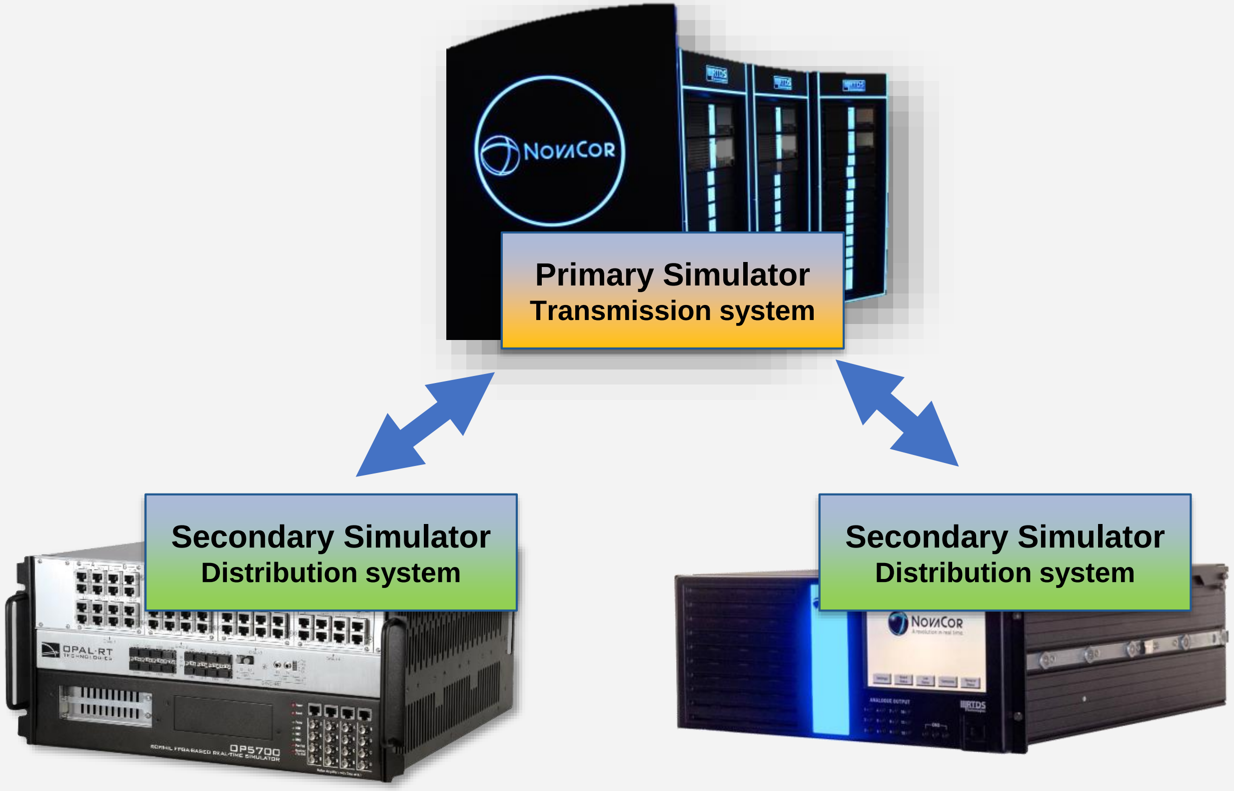
USER SPOTLIGHT SERIES 2.0 BY RTDS Technologies

CONTENT

DISTRIBUTED REAL-TIME SIMULATION

Benefits and approach of distributed Real-Time Simulation:

- Increase of computational power
- Coupling of simulators from different manufacturers
- Interconnection of laboratories for HIL and PHIL
- No exchange of confidential models required
- One simulator operates as primary simulator with which various secondary simulators can co-simulate
- In this case: transmission system is running on primary simulator, distribution systems on secondary simulators



LABORATORY – FAU-LEES

- 6 NovaCor chassis
- 1 Opal-RT OP5707 simulator
- Speedgoat real-time target
- 1 LANTIME M1000 GPS clock
- 6 Omicron amplifiers
- 6 protection devices (SIPROTEC5-7SX85 and PS441 and MiCOM P130C)
- Connection to a PHIL and Micro Grid laboratory by use of amplifiers from Spitzenberger & Spies and Triphase and the Aurora Protocol

Laboratory set up at FAU for HIL

ENERGYLAB 2.0 – KIT-IAI

Hardware Infrastructure

- Numerous Opal-RT simulators
- Busbar matrix connected to:
  - Transformers, converters, PV systems, battery storage units, charging stations and 3 Living Labs
- 1 MVA PHIL system
- Control, Monitoring & Visualization Center
  - Including smart meters distributed throughout the whole campus

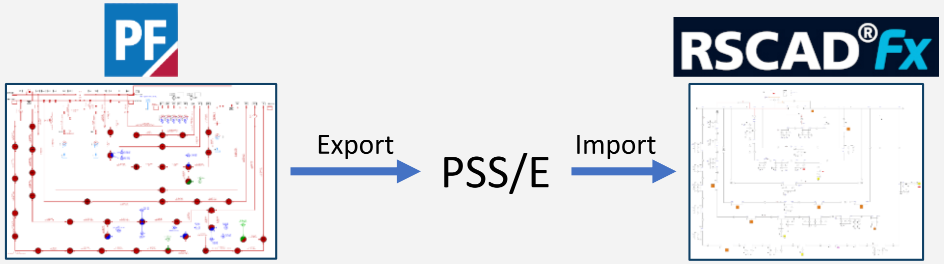
Project info: https://elab2.kit.edu

Karlsruhe Institute of Technology

ENERGYLAB 2.0 – KIT-IAI

Modeling and Simulation Setup

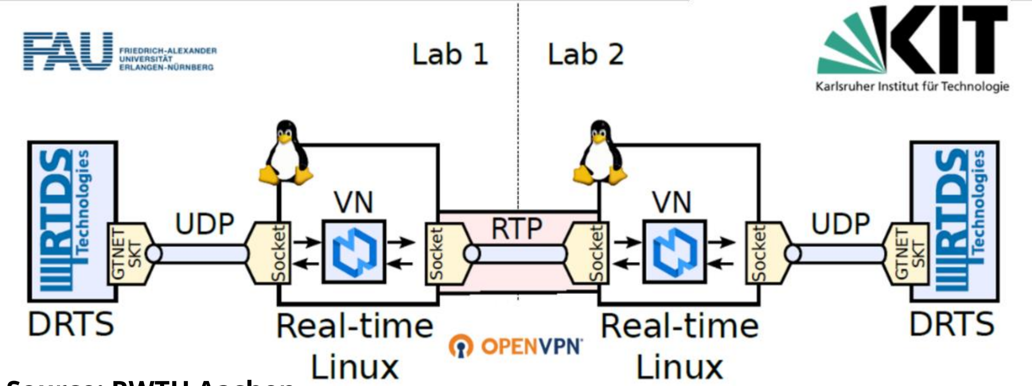
- 3+1 NovaCor chassis with 30 (38) cores in total
- Modeling pipeline:
  - PowerFactory → PSS/E → RSCAD
- Surrounding hardware infrastructure can be interfaced directly, via Aurora or via Ethernet



DISTRIBUTED REAL-TIME SIMULATION

Test setup:

- Coupling of RTDS simulators located in Erlangen (E) and Karlsruhe (K)
- Linear distance between Erlangen and Karlsruhe: 200 km
- Simulator in Erlangen (FAU) is primary simulator, simulator in Karlsruhe (KIT) is secondary simulator
- For the implementation VILLASnode™ of RWTH Aachen is used (compatible with OPAL-RT, RTDS, ...)



Source: RWTH Aachen

Map of Germany

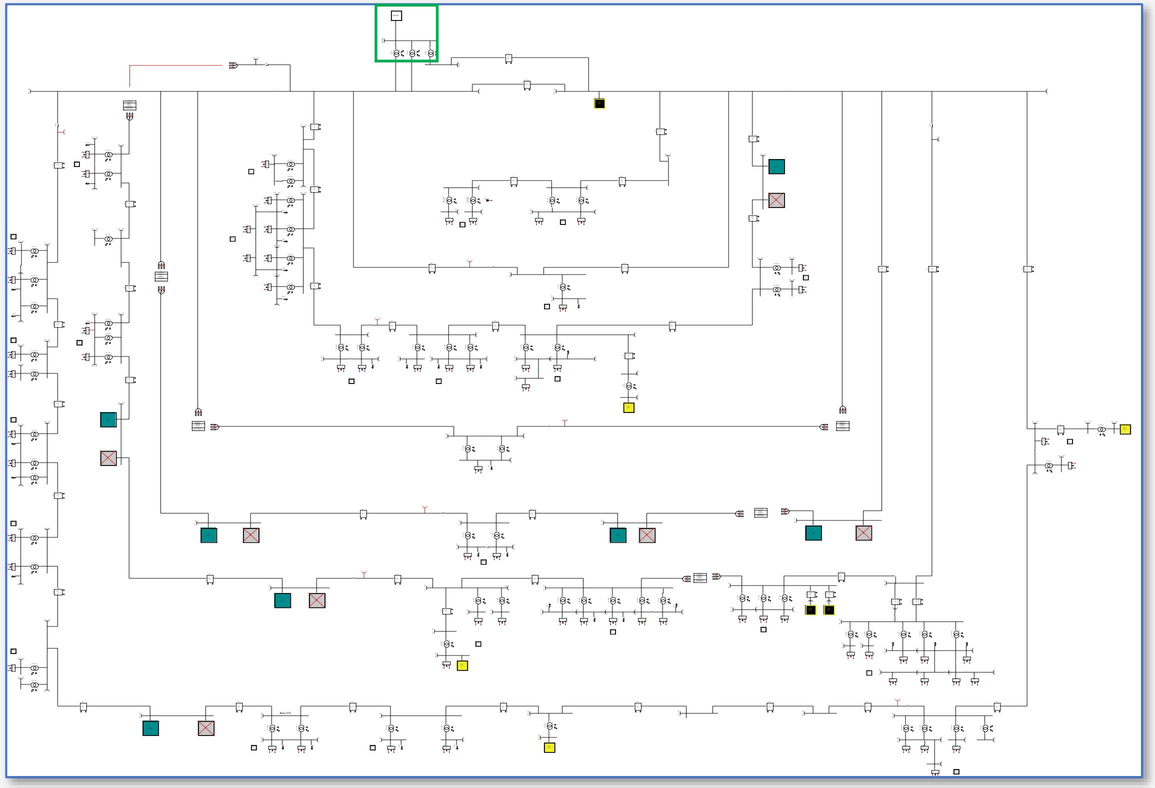
DISTRIBUTED REAL-TIME SIMULATION - MODELS

K

Distribution system

Grid of KIT Campus Nord near Karlsruhe

Controlled voltage source



- 6 20kV-rings with 43 buses
- 4 generators with governor and AVR
- 87 transformers
- 86 dynamic loads, mostly on 400V buses
- Cables as PI-sections due to short length
- Loads and generators can be fed with real historical measurements

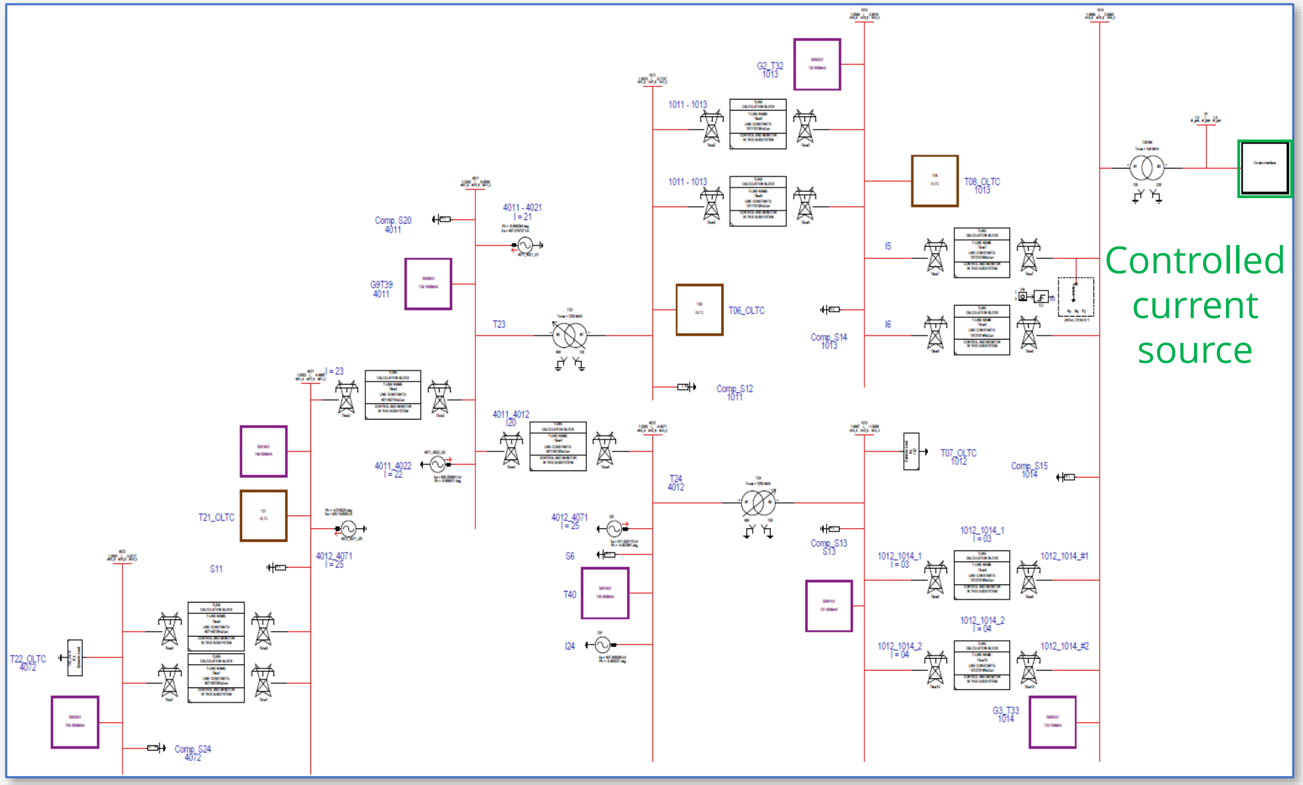
DISTRIBUTED REAL-TIME SIMULATION - MODELS

E

Transmission system

Section of the IEEE Nordic Testsystem

(in future to be replaced by a network model of Northern Germany)



- Generators with Governor & AVR
- Transformers: Step-down with OLTC, step-up & transmission transformer with fixed Tap Changer
- Bergeron Line-model
- Dynamic loads
- LC - compensation

DISTRIBUTED REAL-TIME SIMULATION - MODELS

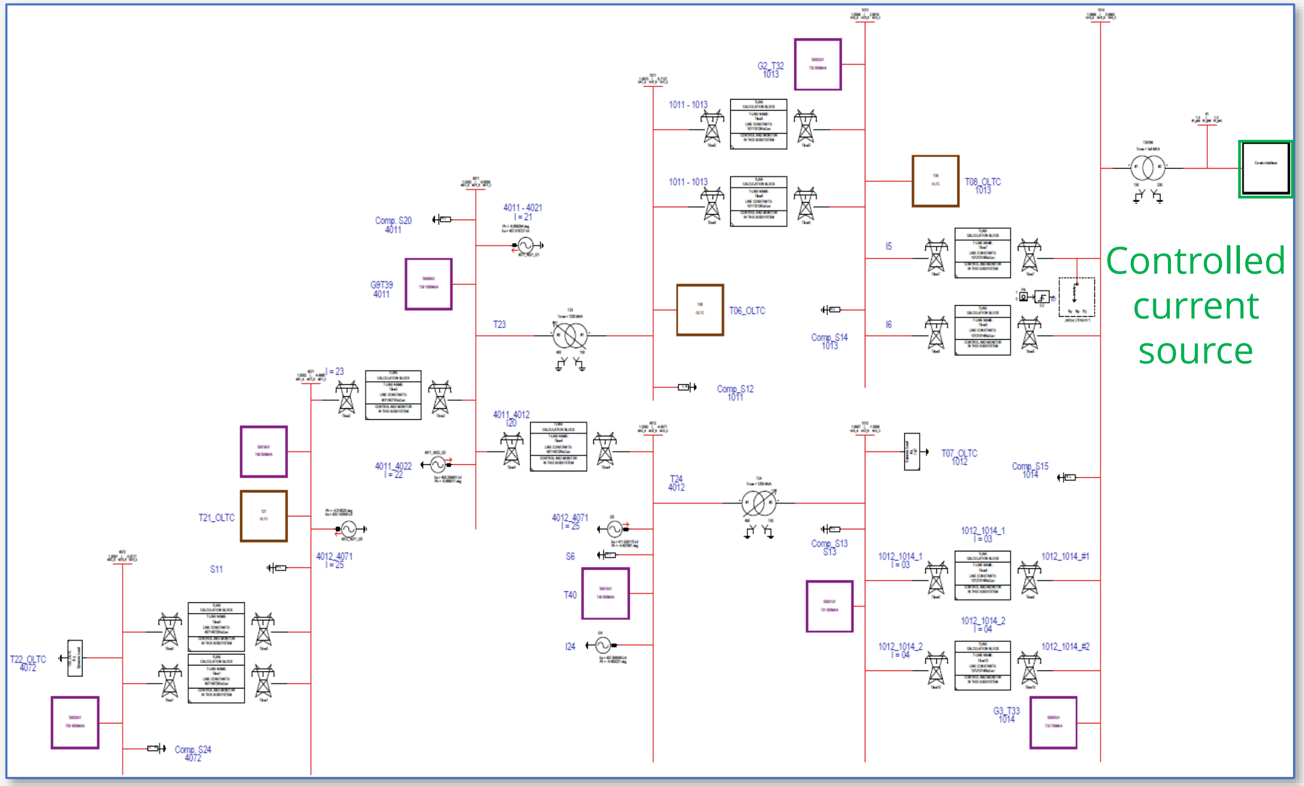
Coupled power systems

E

Transmission system

Section of the IEEE Nordic Testsystem

(in future to be replaced by a network model of Northern Germany)



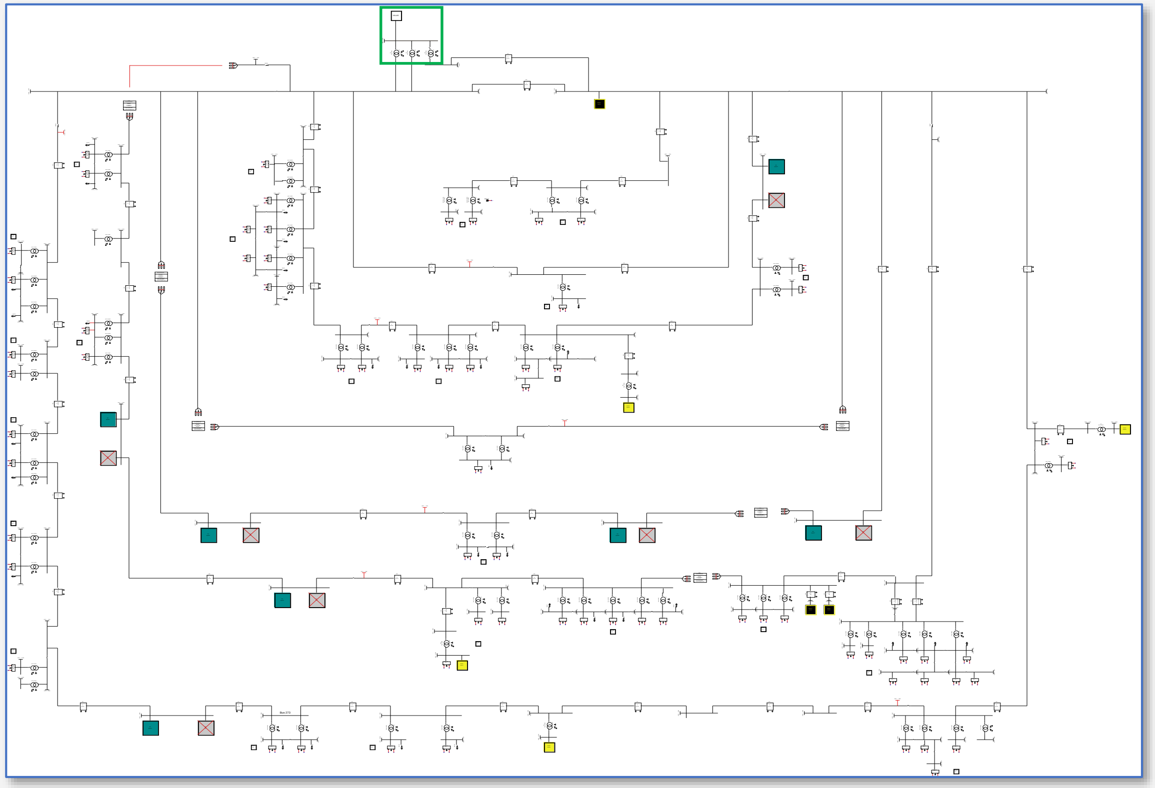
Controlled current source

K

Distribution system

Grid of KIT Campus Nord near Karlsruhe

Controlled voltage source



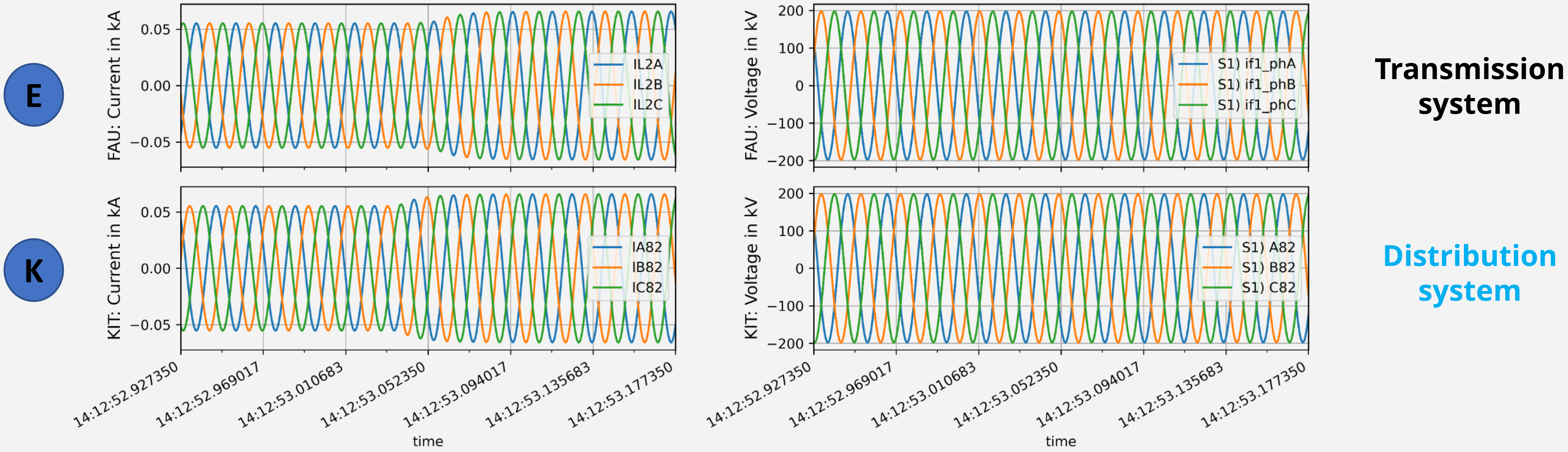
DISTRIBUTED REAL-TIME SIMULATION - RESULTS

Validation:

- Different dynamic simulation cases will be presented
- Validation is carried out without HIL and PHIL

Case 1: Load increase from 1 MW to 4 MW in the distribution system (K)

- Latency in two-digit ms range due to transmission of the signals via the network layer, signals processing in switches and routers



DISTRIBUTED REAL-TIME SIMULATION - RESULTS

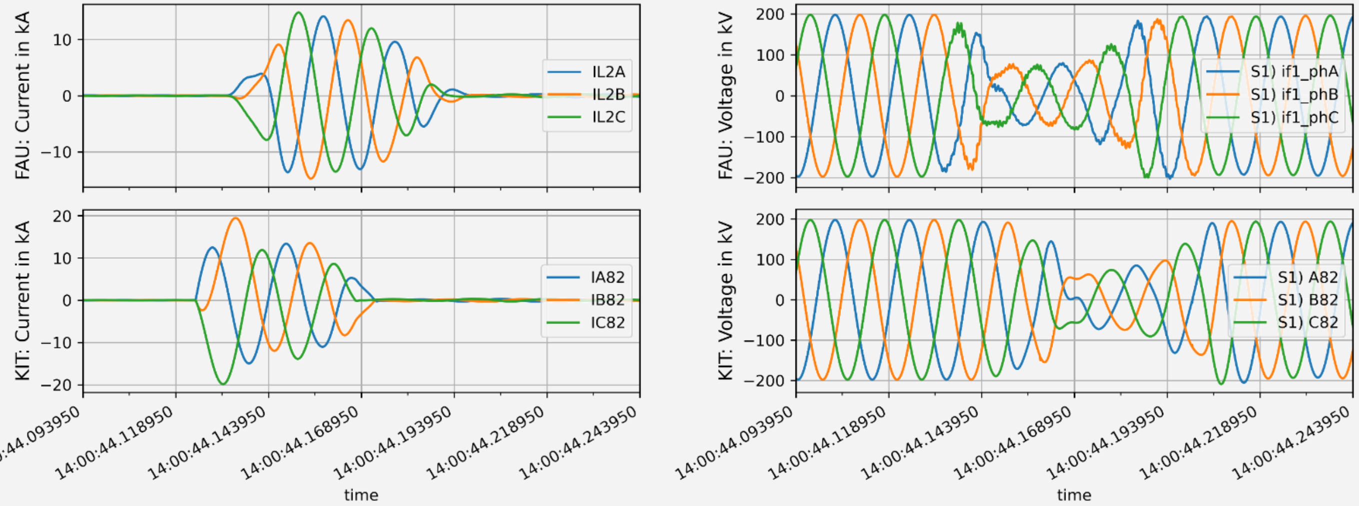
Case 2: Short-circuit in distribution system:
- Fault Location at the coupling node (K)
- Fault impedance of 0,1 ohm

Case 3: Short-circuit in transmission system:
- Fault Location at the coupling node (E)
- Fault impedance of 0 ohm

Short-circuit in distribution system (K)

E

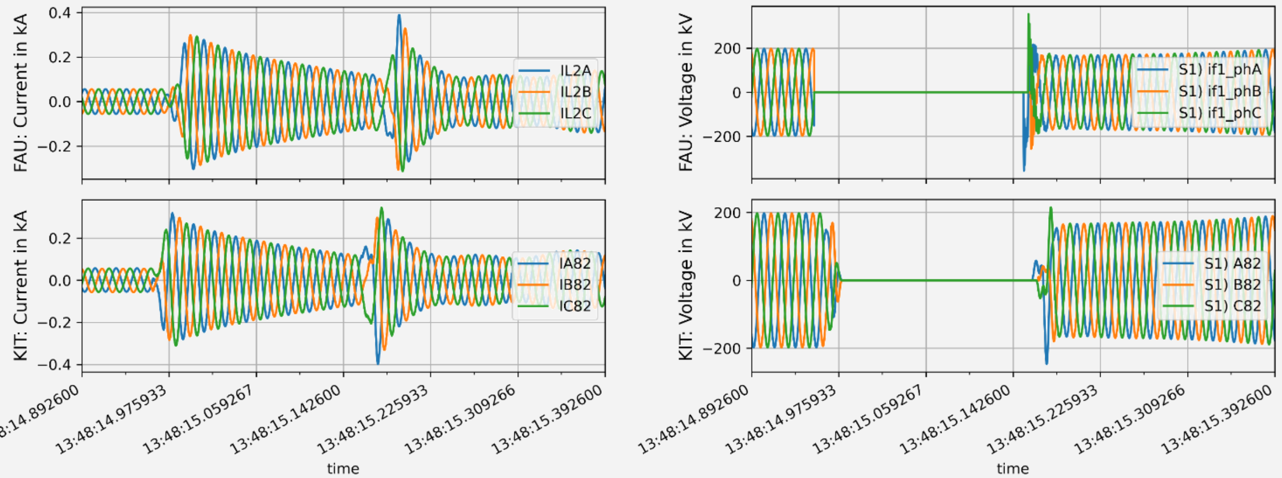
K



Short-circuit in transmission system (E)

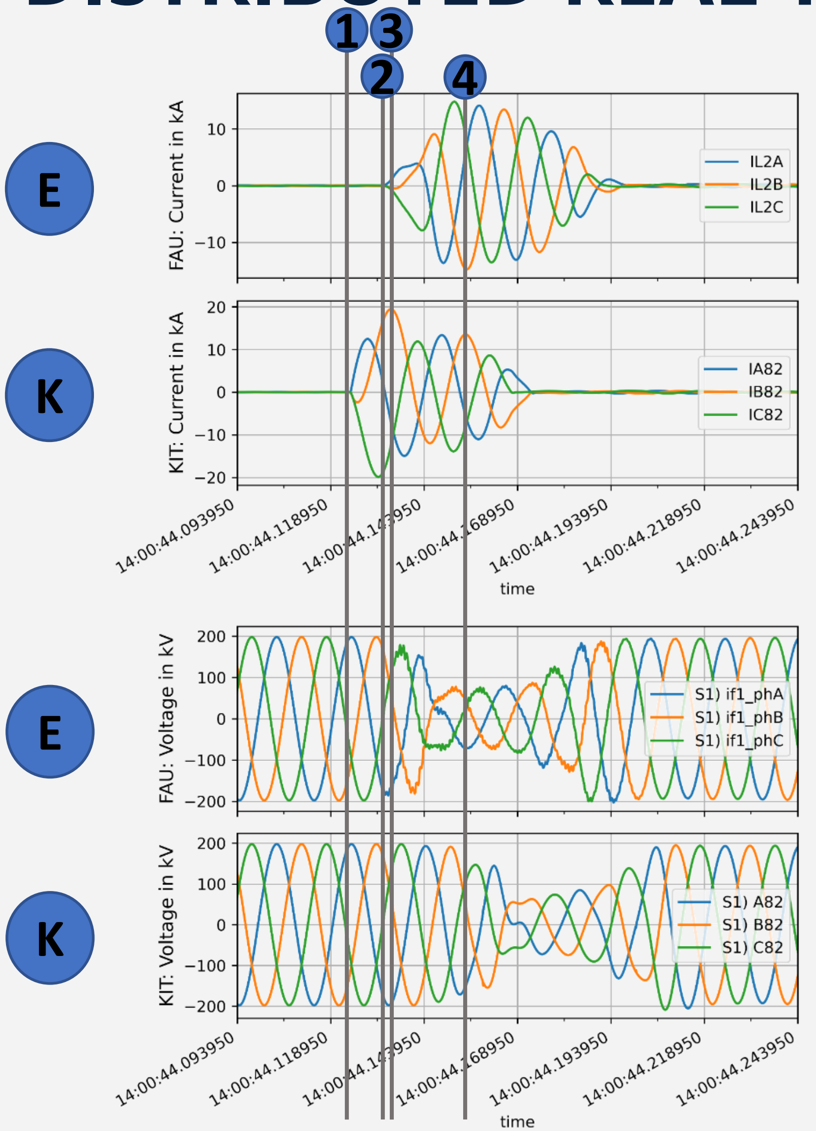
E

K



Conclusions:
- **Distributed Real-Time simulation is working stable even for high dynamics close to the co-simulation connection point.**
- **Latency has impact on travelling waves, as the moment of short-circuit occurrence differs for side (E) and (K).**

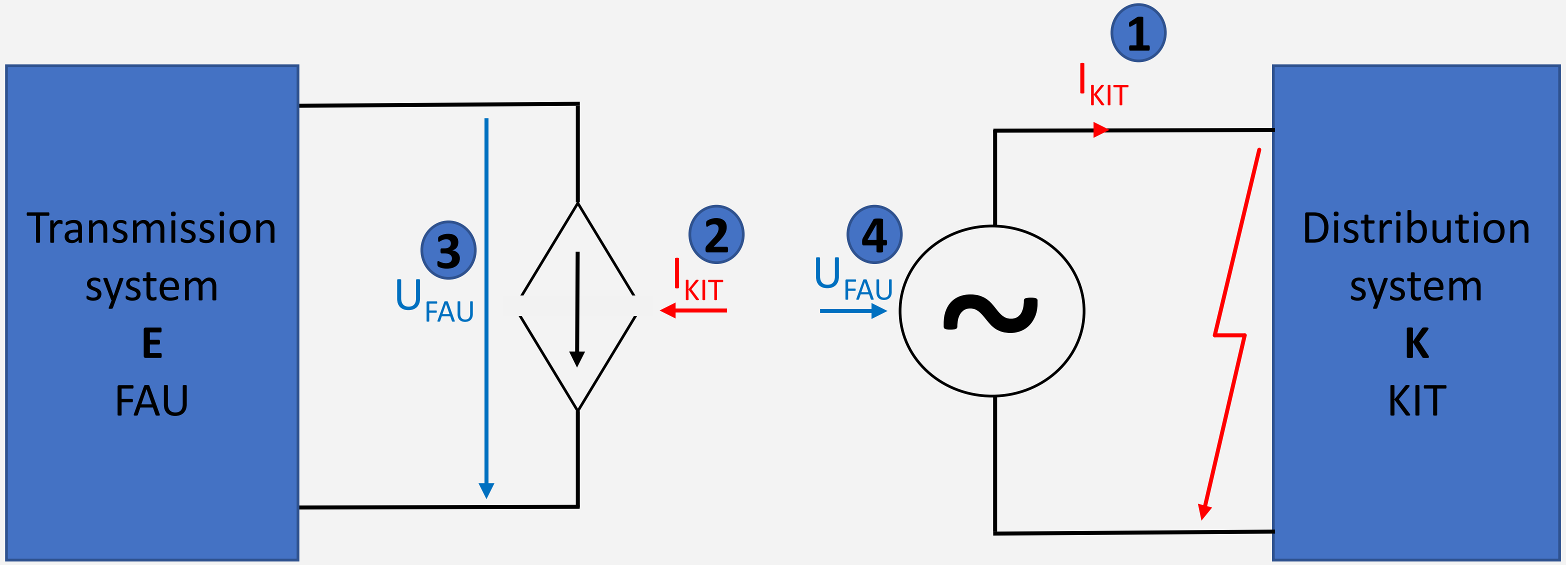
DISTRIBUTED REAL-TIME SIMULATION - RESULTS



Short-Circuit at K (KIT)

1. Increasing Current at K
2. Increasing Current at E
3. Voltage Drop at E
4. Voltage Drop at K

Distribution system



SUMMARY & OUTLOOK

- Establishment of a distributed Real-Time Simulation
- Wide area systems can be modeled on different Real-Time Simulators
- Latencies via network layer and signals processing in switches and routers

- Outlook:
  - Additional connection of a third partner to the transmission grid
  - Different distributed hardware can be connected to the simulation with Power Hardware-in-the-Loop and Control Hardware-in-the-Loop tests
  - Real-Time Scenario: Hybrid AC/DC Test Network
  - Real-Time Scenario: Multi-Modal Gas/Power Grid

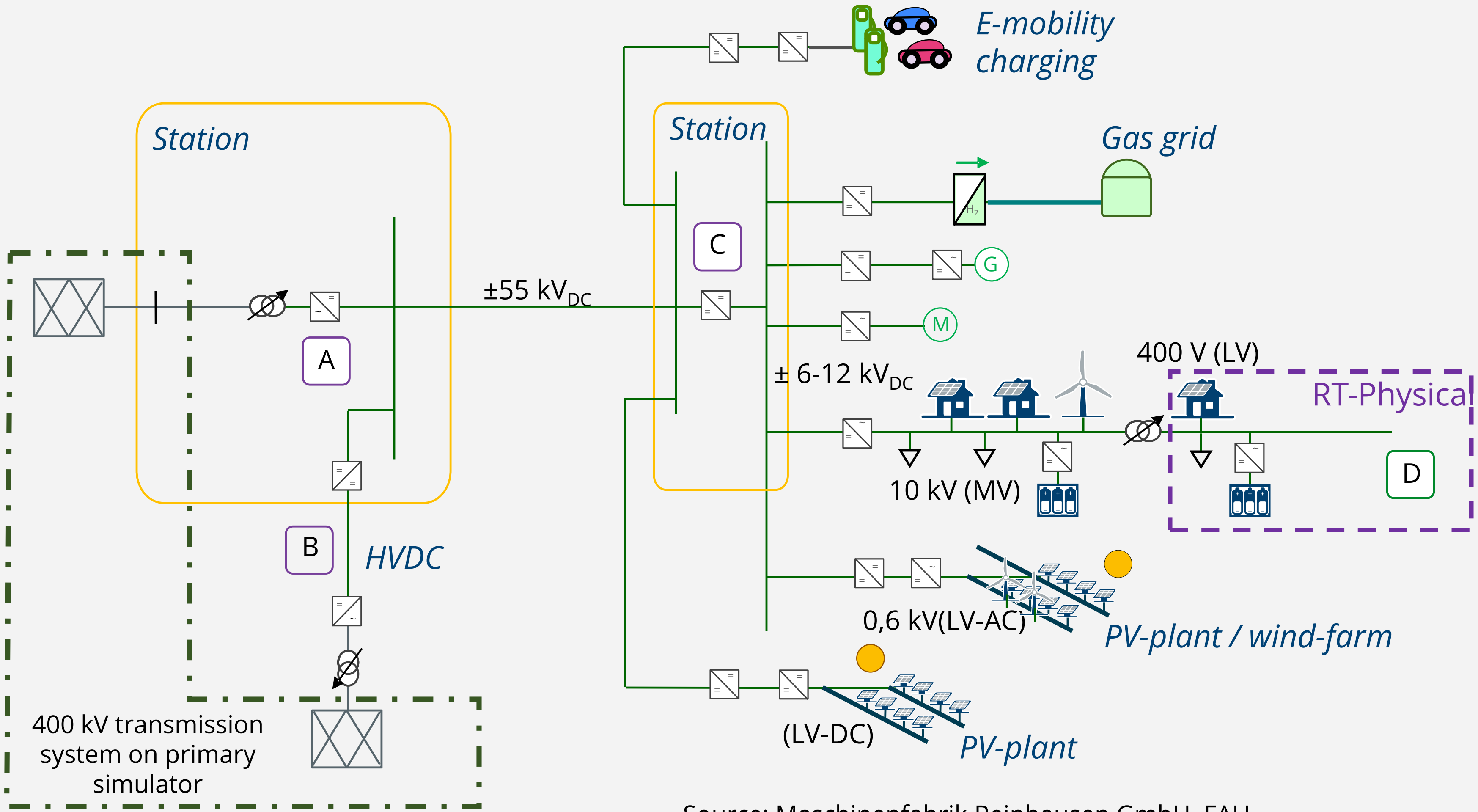
REAL-TIME SCENARIO: HYBRID AC/DC TEST NETWORK

Multi-purpose
hybrid AC/DC test network

Scenario objectives:

- Interaction of local controllers
- Grid-forming control
- Islanding
- Evaluation of system stability
- Selectivity

Picture shows principle approach, final implementation can differ



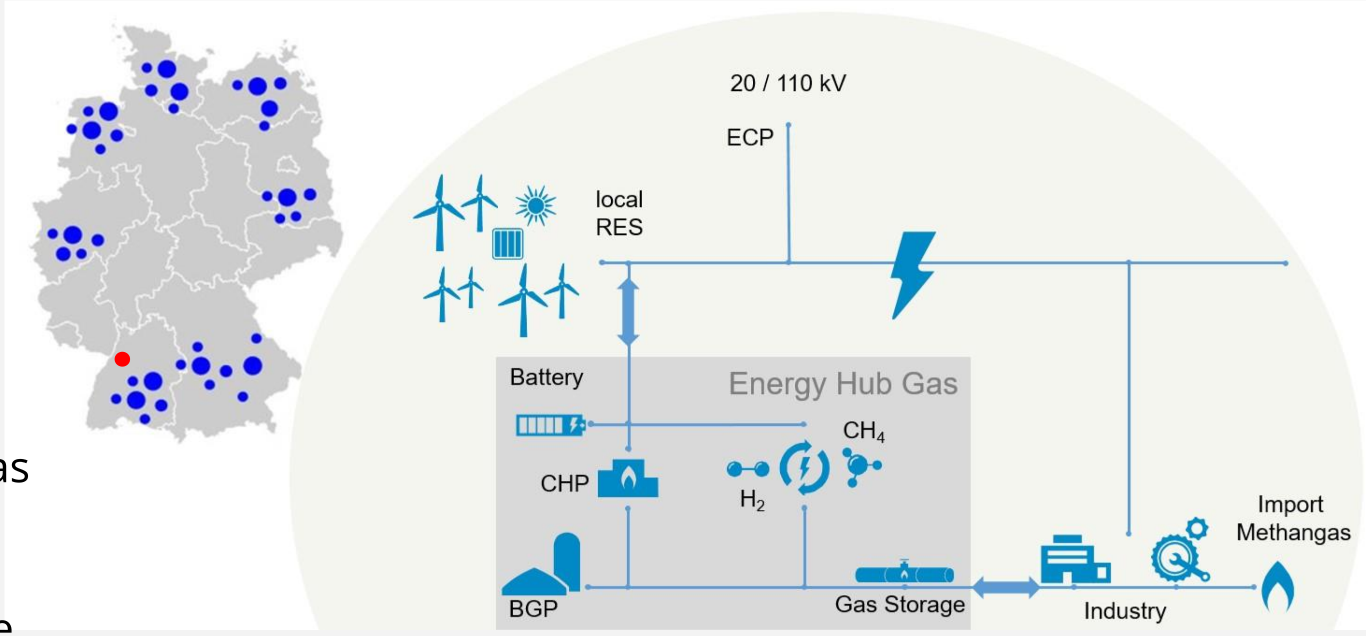
Source: Maschinenfabrik Reinhausen GmbH, FAU

REAL-TIME SCENARIO: MULTI-MODAL GAS/POWER GRID

Simulative integration of a 'Regenerative Energies Hub' into a trans-regional grid

Scenario objectives:
- Efficient use of the gas grid and distributed storage capacities (e-mobility) to support the power grid
- Conditions for profitable operation of RE-Hubs

RE-Hub (model or real equipment):
- *Storage*: gas storage (H_2, CH_4 and CO_2), batteries
- *Gas-to-Power/Power-to-Gas conversion*: electrolyzers, biomass fermentation, combined heat and power gas motors, synthetic methanization
- Interfaces to 20kV/110kV and trans-regional gas grid
- Regional outlets to e-mobility charging infrastructure, industry and heat processing



ECP – Electrical Connection Point, BGP – Biogas Plant, CHP – Combined Heat and Power

THANK YOU FOR THE ATTENTION ☺

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