FI SMEP

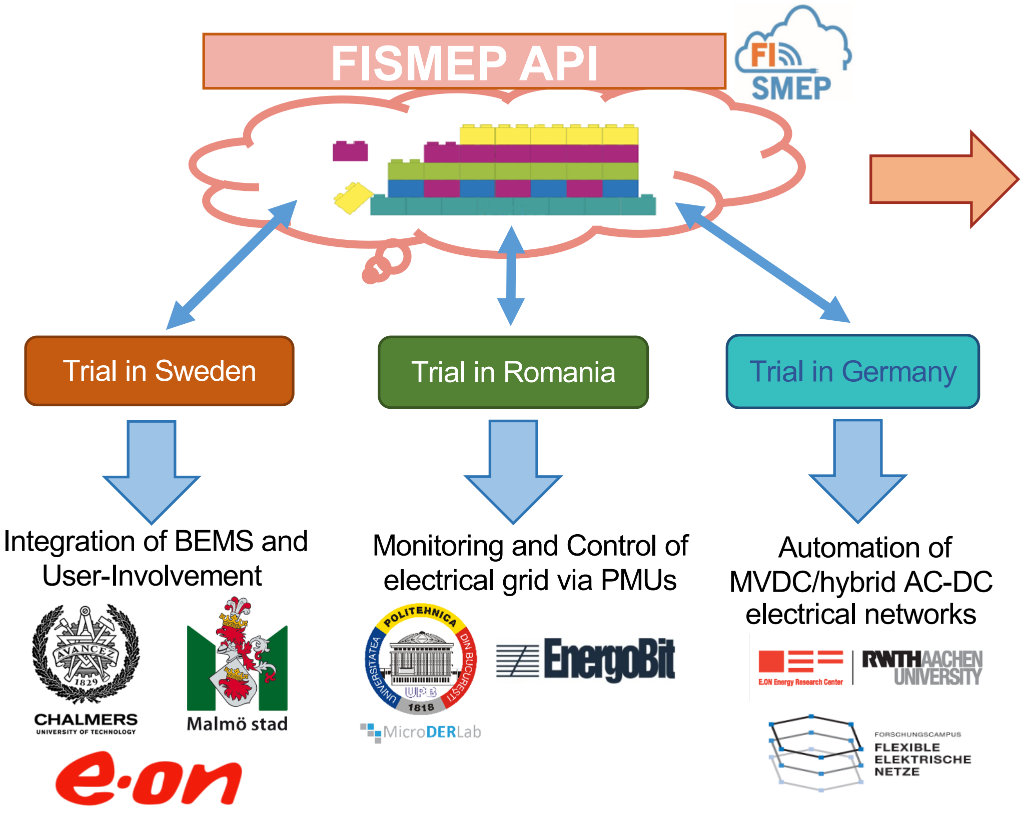
FIWARE for Smart Energy Platform

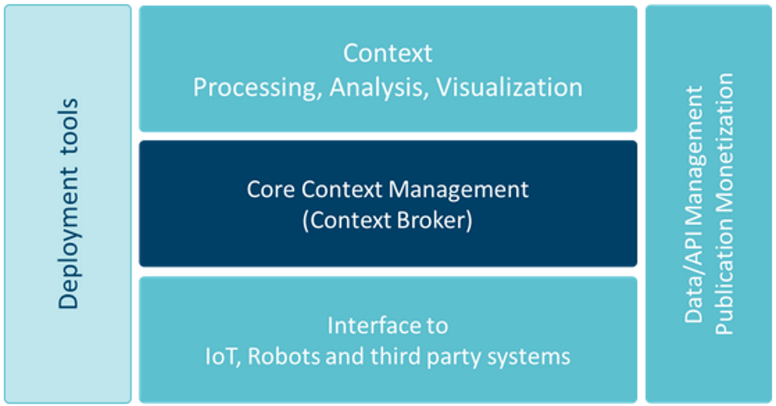
FISMEP: FIWARE FOR SMART ENERGY PLATFORM

This project has received funding in the framework of the joint programming initiative ERA-Net Smart Grids Plus, with support from the European Union’s Horizon 2020 research and innovation programme.

Smart Grids Plus
ERA-Net

Project Overview



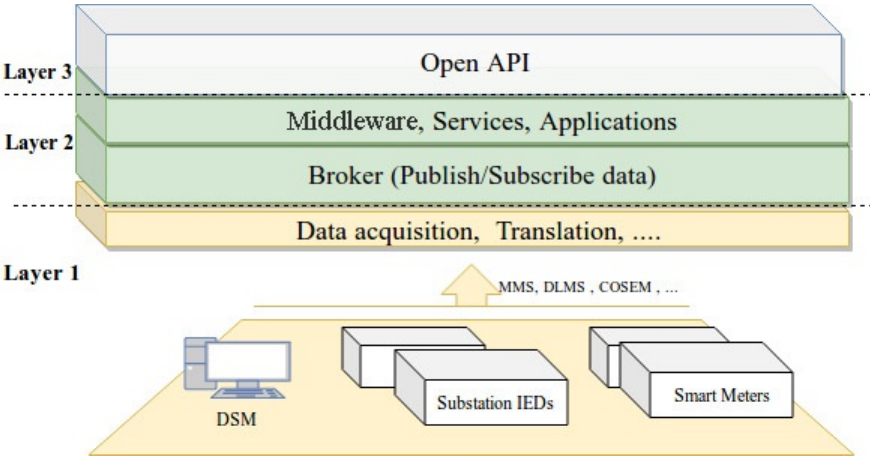


FIWARE
Open APIs for Open Minds

Architecture Structure

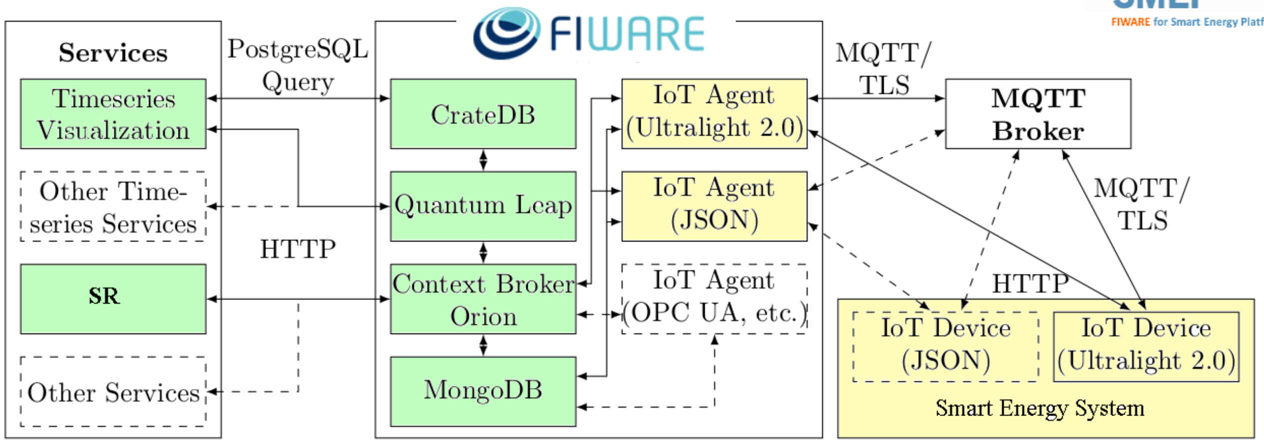
Multi-layered **Servie-Oriented Architecture (SOA)**:

- Layer 1: Data acquisition, mapping of raw data to standardized models and transmission
- Layer 2: generic and specific domain middlewares; manage and analyze time-series data, SR and visualization
- Layer 3: publicly available API; open access to back-end data



Architecture Components

- **Yellow blocks:** data collected from the field, components in layer 1
- **Green blocks:** analysis of data and SR, components in layer 2

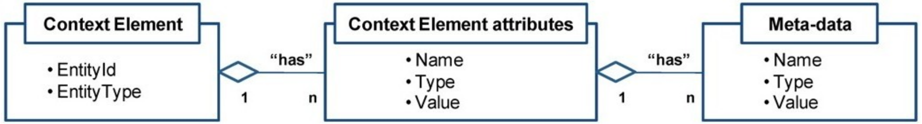


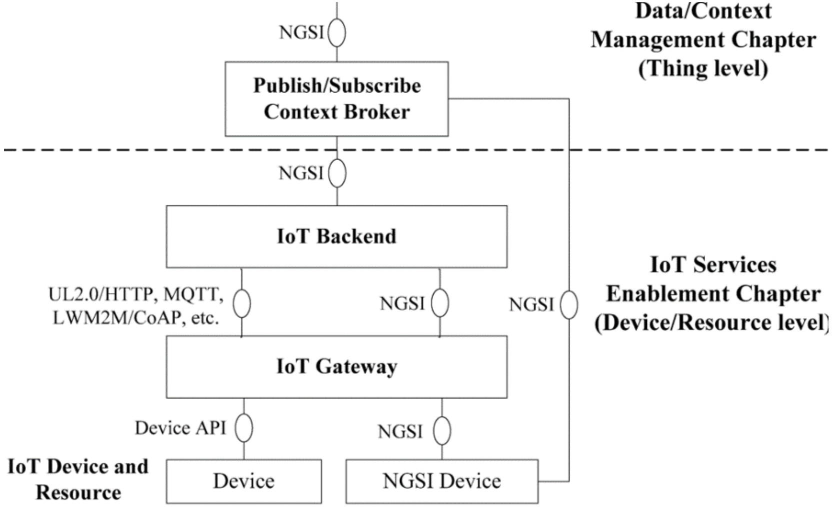
- FIWARE: open European project for smart application in several domains
- Key component is constituted by the Orion Context Broker:
  - Process context information and data streams, in real time and distributed format
  - Publish/subscribe of data through Next Generation of Service Interface (NGSI)

NGSI and IoT Agent

- NGSI defines entities as physical objects (sensors and actuators) or software:
  - ID
  - Attributes (static or dynamic)
  - Linked data for semantic representation

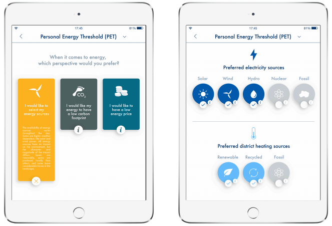
- Data collected from the field devices via **IoT Agent**:
  - IoT Backend, management of IoT devices in the cloud
  - IoT Gateway, protocol or standard adapter with communication layer to host environment





Field Test in Sweden: ERO app & CESO platform

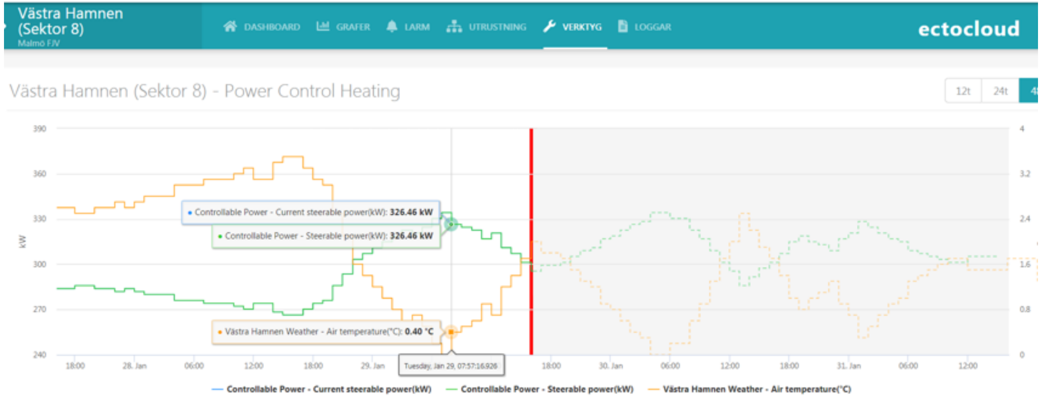
- ERO is an app for the residents of HSB Living Lab of Chalmers University (Gothenburg – SE), to plan the energy sources to use and check their access to the electricity and heating systems.
- ERO elaborates the user's activity and gives recommendations about energy usage.



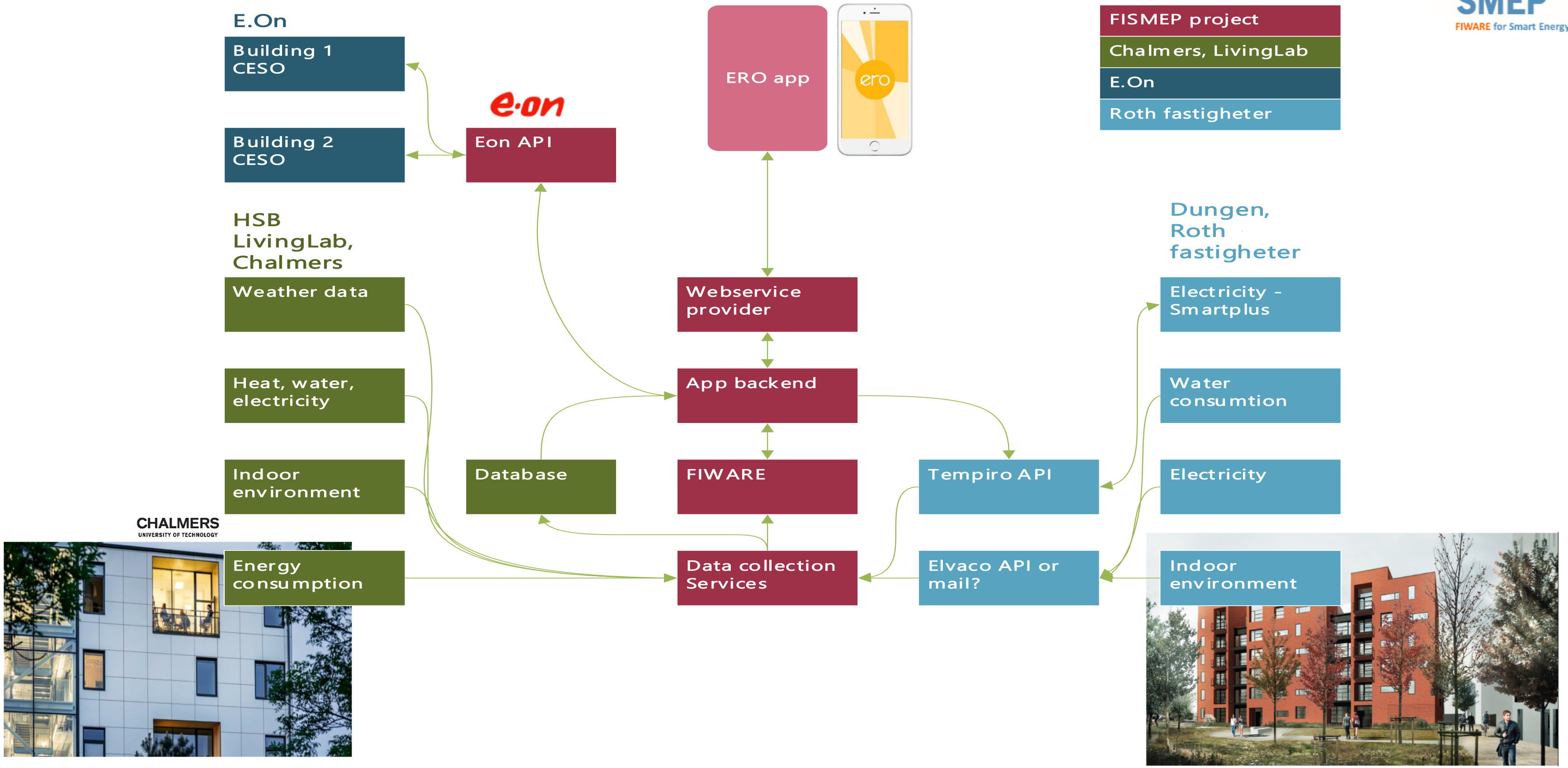
Setting up the Personal Energy Threshold

The energy availability tab

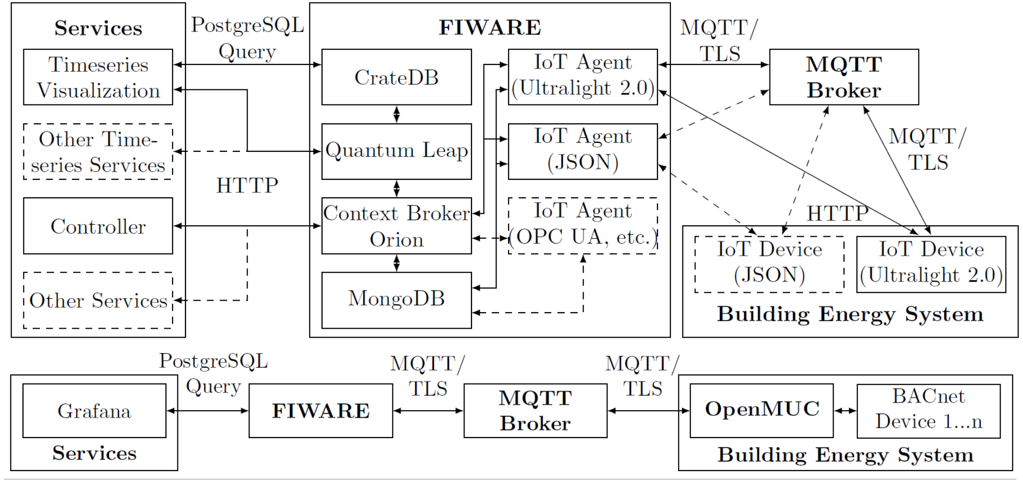
- The smart grid platform CESO enables a digital connection of the customer to E.ON grid.
- CESO focuses on optimizing energy carriers' district heating, district cooling and electricity production and distribution.

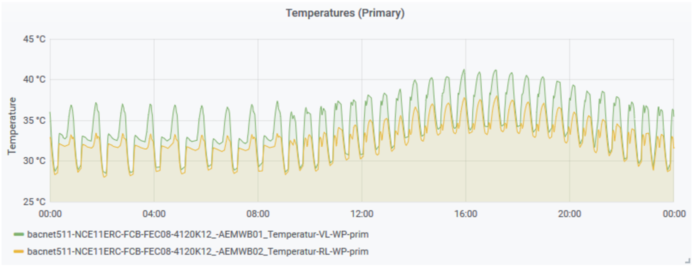


Field Test in Sweden



Building Monitoring Platform in RWTH Aachen University





Romanian Field Test

System architecture: collection of data from several Phasor Measurement Units (PMUs) installed in the transmission network.

PMU STRUCTURE OF DATA

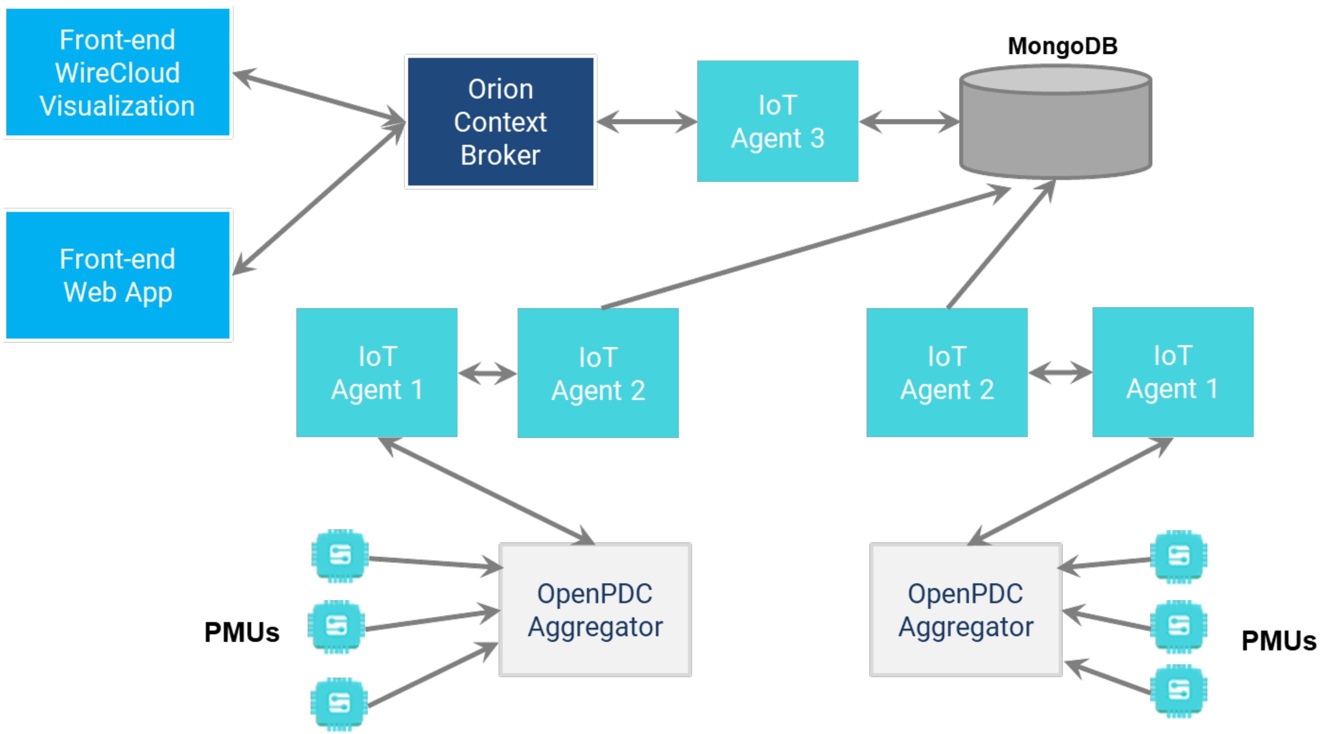
ID: “ID protocol/IP”
Type of the PMU: “Arbiter/SEL/…”
Installation time:
Reporting rate:
Location:
- Substation:
- Type of Cell:
- GPS Coordinate:

Grid information:
- Voltage level
- Voltage transformer
- Current transformer

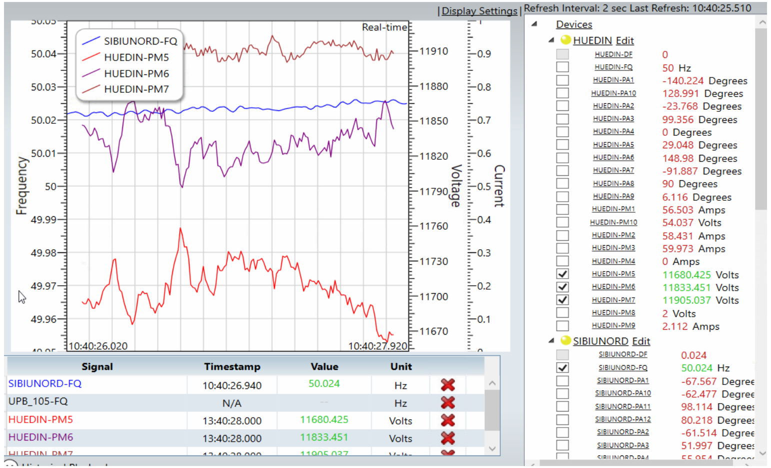
RELEVANT INFORMATION

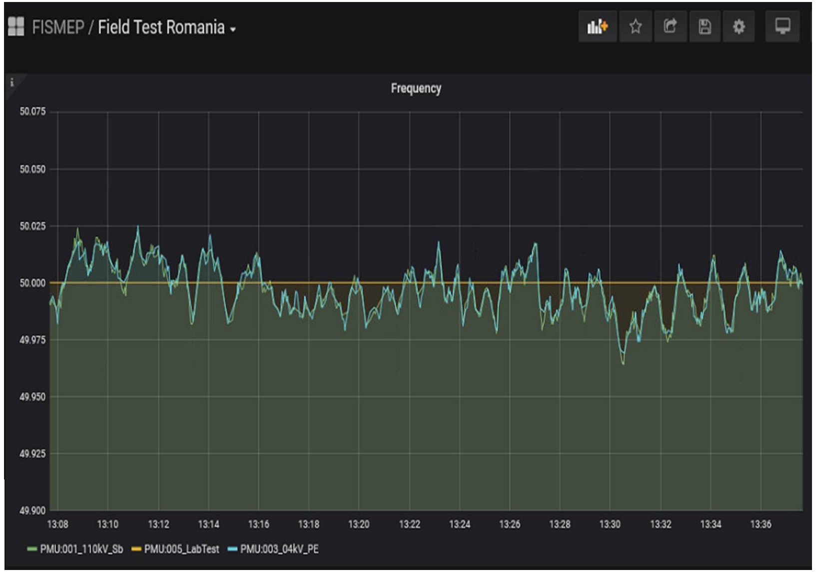
Time
f – value
rocof – value
U1 – mag, angle
U2 – mag, angle
U3 – mag, angle
U+ – mag, angle
U- – mag, angle
U0- mag, angle
I1 – mag, angle
I2 – mag, angle
I3 – mag, angle
I0 – mag, angle
I+ – mag, angle
I- – mag, angle

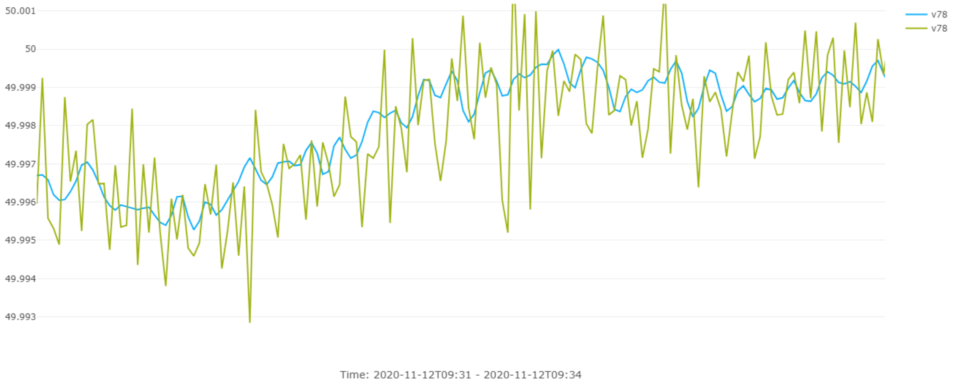
PMU Integration: Overall Architecture



PMU: Monitoring with FISMEP







German Field Test: Motivation

Transformation of Electrical Power Systems: IoT devices and new grid actors

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Smart Grid Automation

↓

Continuous monitoring and analysis of vast amount of collected data

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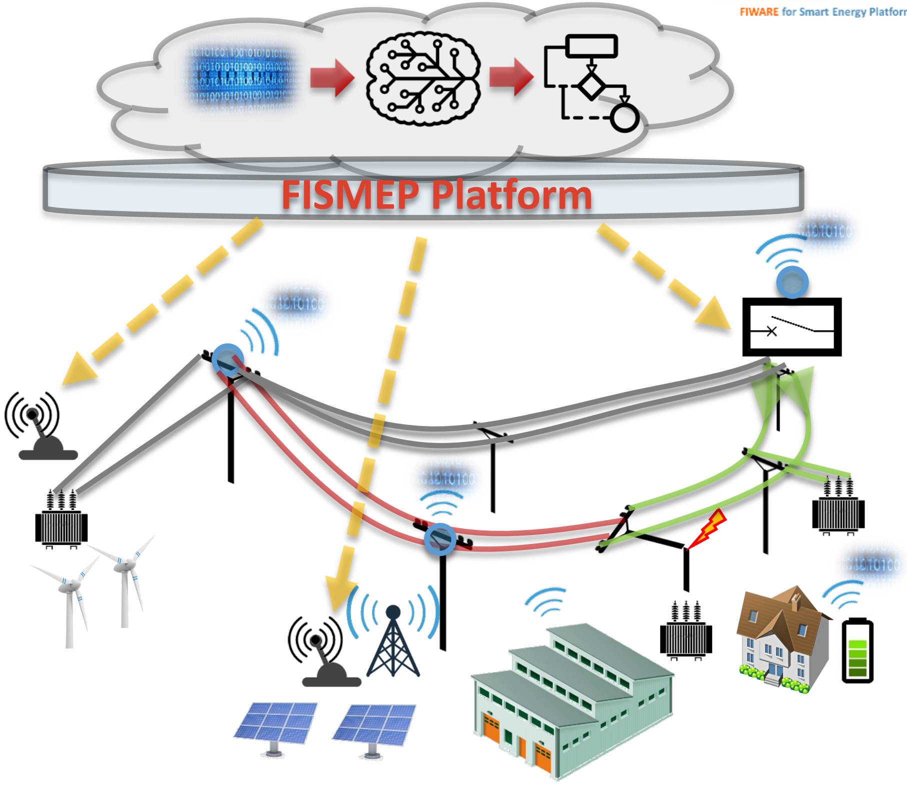
High computing power and time-consuming algorithms



Cloud architectures with distributed system services: **middleware**

- standards APIs and protocols

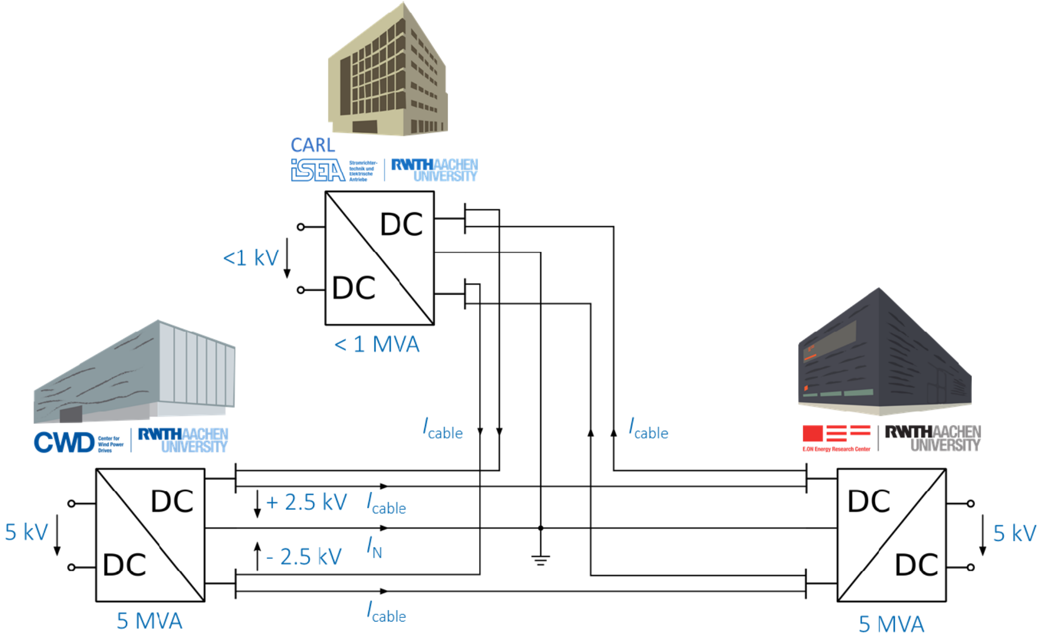
FISMEP: German Field Test

- Deployment of the platform, tailored to the management of power distribution grids, based on FIWARE technology:
  - Monitoring of Medium-Voltage DC grid
  - Service Restoration as middleware
  - Network Reconfiguration for AC-DC grids
- Test setup:
  - FEN research grid
  - Grid modelling via Real-Time Digital Simulator (RTDS) and fault detection provided via IEC 61850 - GOOSE
- Lite Emulator of Grid Operations (LEGO)

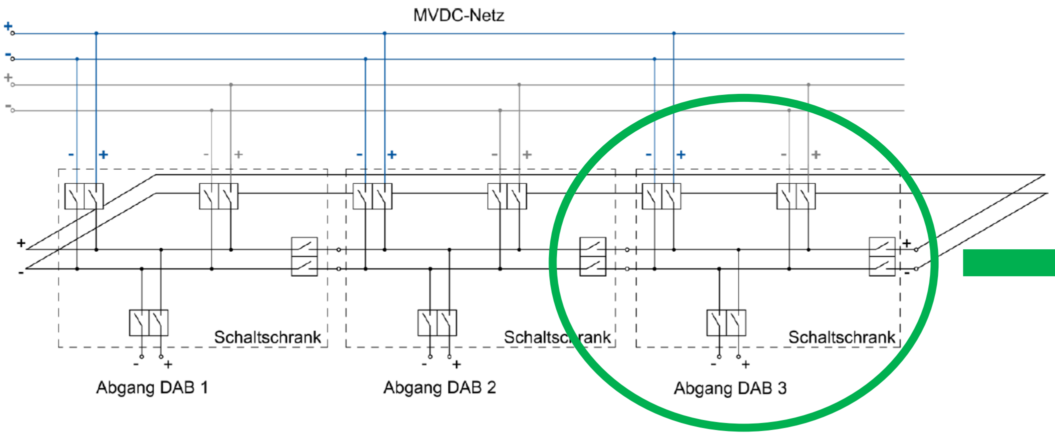
FEN Researh Grid

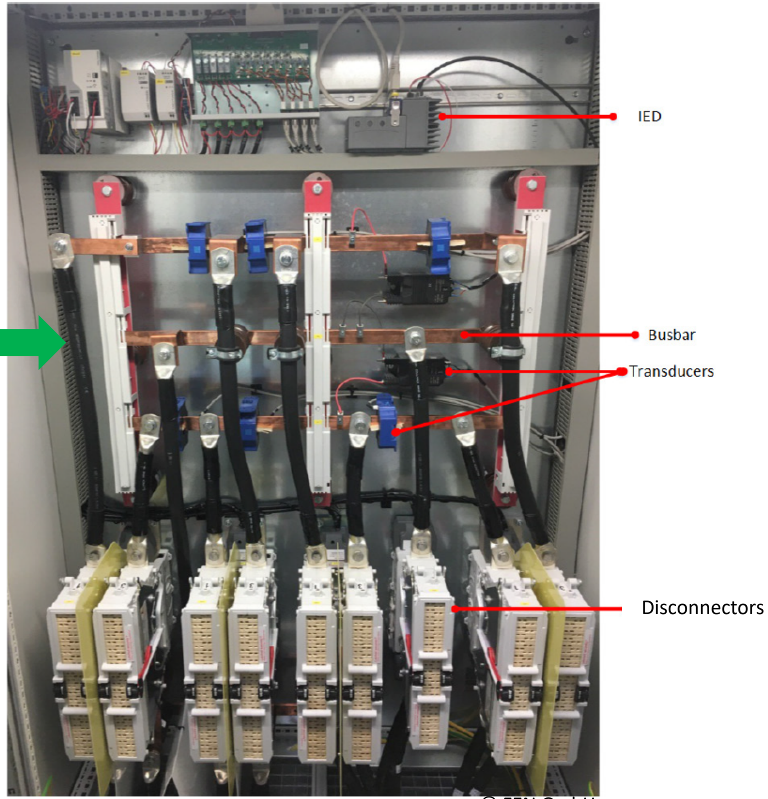
Medium-Voltage Direct-Current (MVDC) grid:

- 5km cables at 5kV
- Two Medium-Voltage Alternating Current (MVAC) grid operators connections
- High-power DC/DC and DC/AC converters to form hybrid AC/DC grid structures
- Voltage and current measurements at grid connection points and in high-power converters



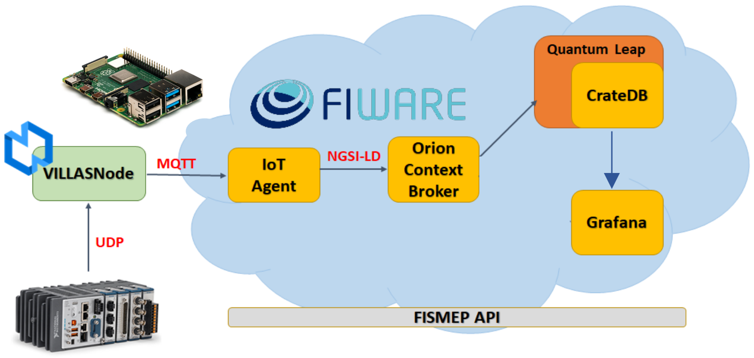
FEN Research Grid

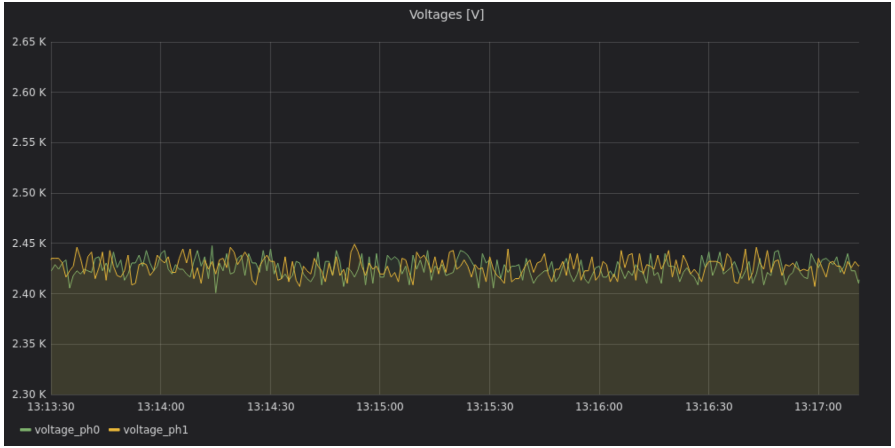


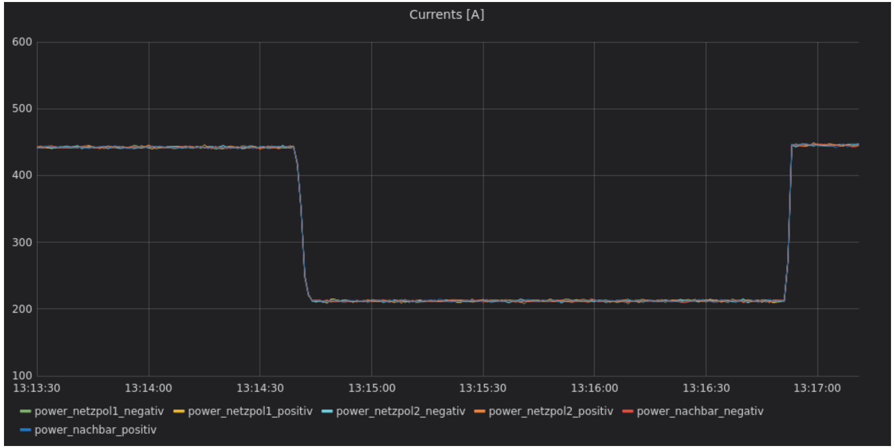


MVDC Automation with FISMEP

- Measurements from field devices, transducers and converter controllers collected by IEDs
- Data are provided via the VillasNode gateway component accroding to MQTT protocol.
- The FISMEP cloud platform deploys monitoring and management of the electrical network





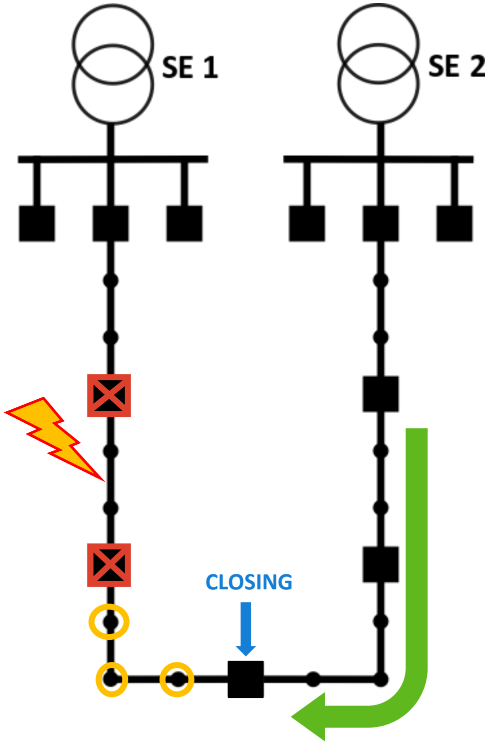


Service Restoration Concepts

- Traditionally, fault management actions are carried out by human operators
- Distribution Management Systems (DMS) deploys fully automated Fault Location, Isolation and Service Restoration (FLISR):
  - Prompt intervention of protection
  - Minimization of outage consequences
  - Recovery to healthy condition

Improvement of reliability indeces:

- SAIDI
- CAIDI



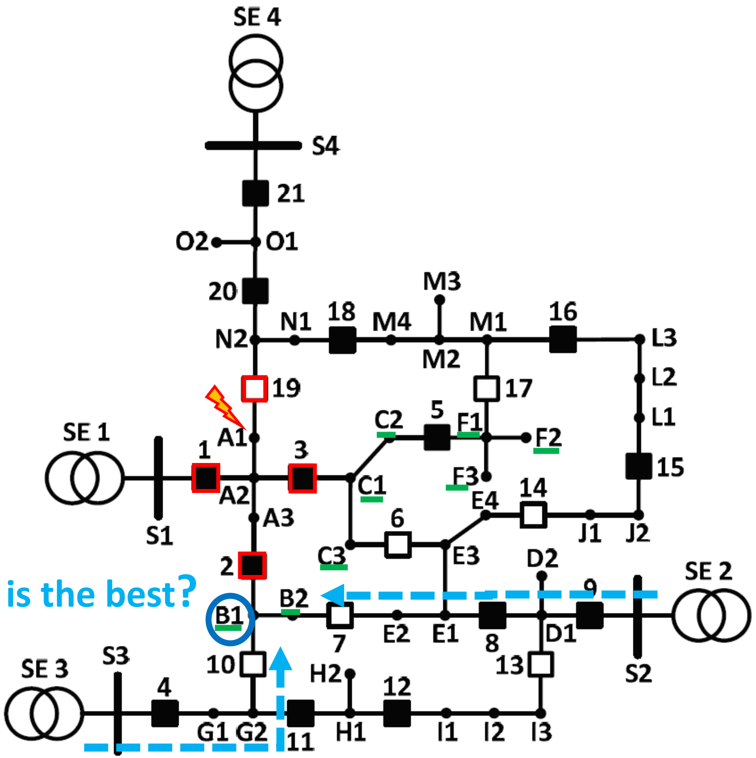
Determination of the Reconfigurable Paths

- Target restoration load according to priority index λ → hospital, transportation, communication, gas network site

- For each substation present in the network:
  - most suitable path toward the load
  - using the Dijkstra's algorithm for shortest path:

$$Z_a^b = min \sum_{x,y \in G'_{a,b}} |\overline{Z}_{x,y}|$$

- Set of candidates that include the closing of a tie-switch (normally open switch – white square)



Assessment: State Estimation + Constraints

- Each candidate for network configuration is checked with State Estimation (SE) approach:
  - Weighted Least Square (WLS)
  - Voltage and power injections (active and reactive) as measurements
- Check of the following constraints:

1. **Radiality:** substations electrically disconnected from each other
2. **Voltage Limits:**

$$0.9V_n < \left|\overline{V}_x\right| \pm 3\mu_{\left|\overline{V}_x\right|} < 1.1V_n$$

3. **Loading Limits:**

$$\left|\overline{I}_{x,y}\right| + 3\mu_{\left|\overline{I}_{x,y}\right|} < I_{max_{x,y}}$$

! **Eventually, temporary emergency condition (120% $\mathbf{I_{max}}$)**

Selection of Optimal Topology

The optimal solution is identified by considering two criteria:

1. Total power losses

$$P_{x,y}=3\Re\left[\overline{V}_x\underline{\left(\overline{V}_x\frac{G_{+}+jB_{+}}{2}\right)}+\overline{V}_y\underline{\left(\overline{V}_y\frac{G_{+}+jB_{+}}{2}\right)}+\left(\overline{V}_x-\overline{V}_y\right)\underline{\left(\frac{\overline{V}_x-\overline{V}_y}{R_{+}+jX_{+}}\right)}\right]$$

2. Utilization of electrical lines

$$\theta_{x,y}=\frac{I_{max_{x,y}}-\left|\overline{I}_{x,y}\right|}{I_{max_{x,y}}}$$

The three minimum values of $\theta_{x,y}$ are recorded: θ_1, θ_2, θ_3

Four parameters: P, $\boldsymbol{\theta_1}$, $\boldsymbol{\theta_2}$, $\boldsymbol{\theta_3}$

Multiple-Criteria Decision Analysis

1. Analytical Hierarchy Process (AHP) is implemented, to define the comparison matrix:

$$A = \begin{bmatrix} 1 & w_{P\theta_1} & w_{P\theta_2} & w_{P\theta_3} \\ \frac{1}{w_{P\theta_1}} & 1 & w_{\theta_1\theta_2} & w_{\theta_1\theta_3} \\ \frac{1}{w_{P\theta_2}} & \frac{1}{w_{\theta_1\theta_2}} & 1 & w_{\theta_2\theta_3} \\ \frac{1}{w_{P\theta_3}} & \frac{1}{w_{\theta_1\theta_3}} & \frac{1}{w_{\theta_2\theta_3}} & 1 \end{bmatrix}$$

Comparison of importance among P and θ_1

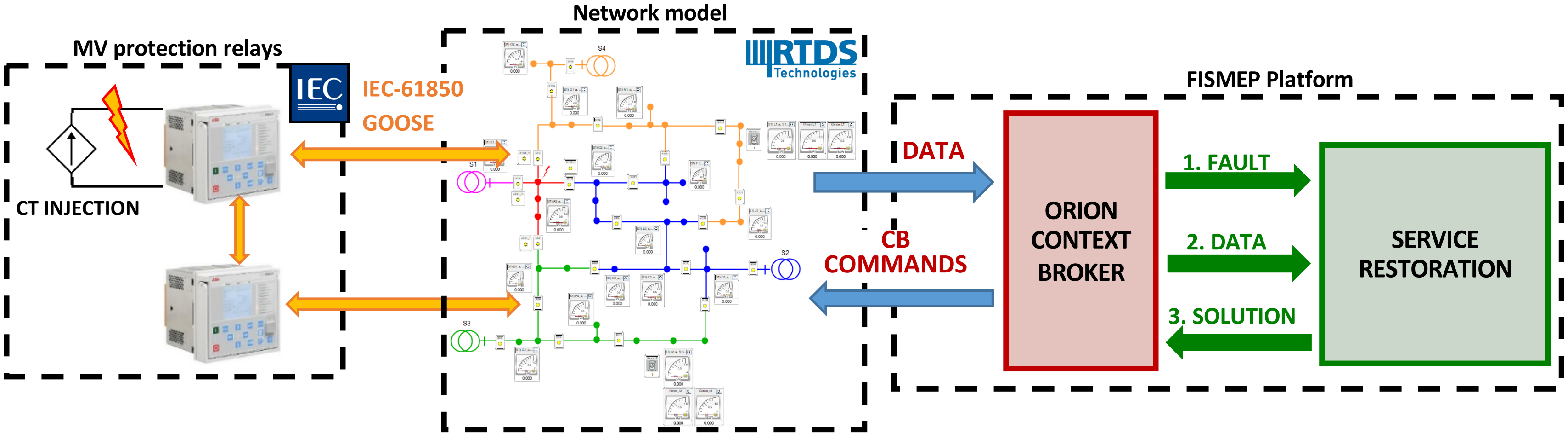
2. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS): distance of each candidate solution to the positive and negative ideal ones

$$A^+ = \{v_1^+, \dots \dots \dots v_n^+\}$$
$$where\ v_j^+ = \{\max(v_{ij})\ if\ j \in B\ ; \min(v_{ij})\ if\ j\ \in C\}$$

$$A^- = \{v_1^-, \dots \dots \dots v_n^-\}$$
$$where\ v_j^- = \{\min(v_{ij})\ if\ j \in B\ ; \max(v_{ij})\ if\ j\ \in C\}$$

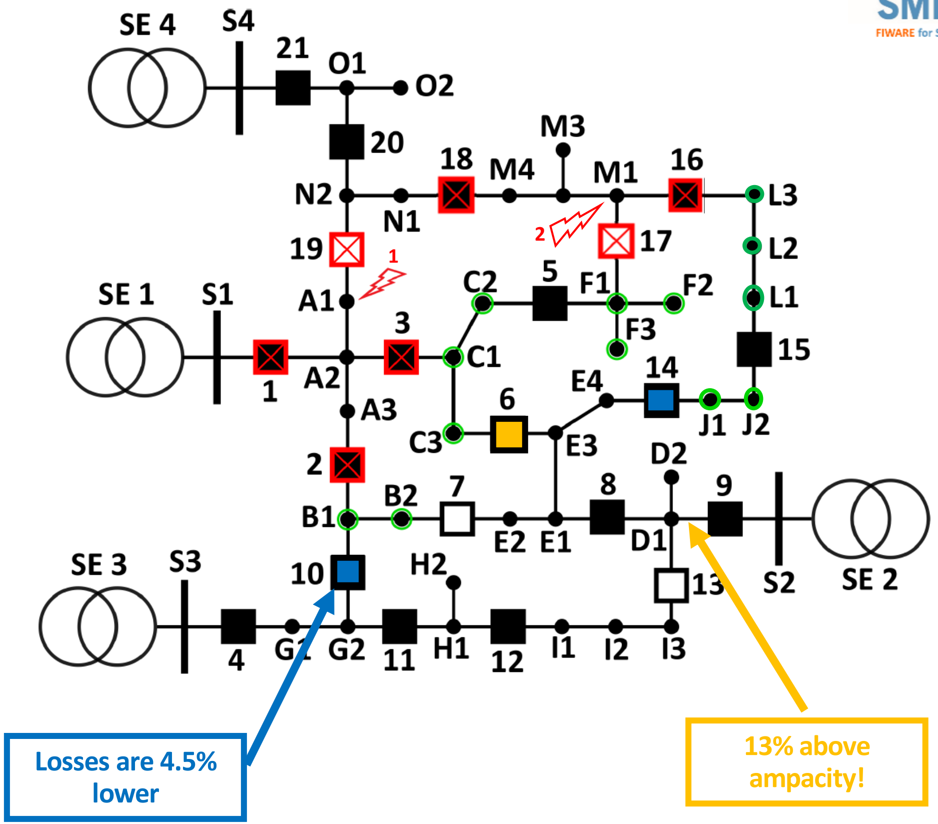
Service Restoration as Middleware: Control Flow

- Data are provided from the electrical network to the platform via HTTP
- Orion Context Broker (CB) notifies the received data about **tripped circuit breaker:**
  1. SR is activated and retrieves actual network data from CB
  2. SR computes the reconfiguration solution and communicates it to CB
  3. The closing operating command is issued to switches in the electrical network
  4. Process repeats until all possible devices are re-connected



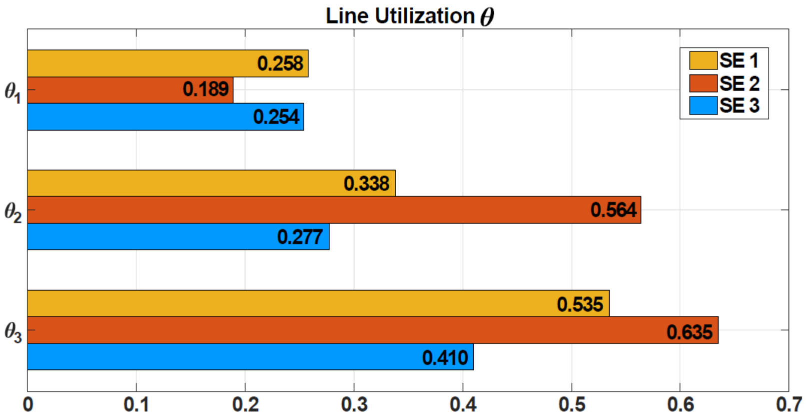
Assessment Cases I

- As test grid, a 13.8 kV distribution network with passive and active loads (100 kW – 1MW)
- The computation process considers the minimization of power losses as target
- The Service Restoration proved the adaptability to multiple faults

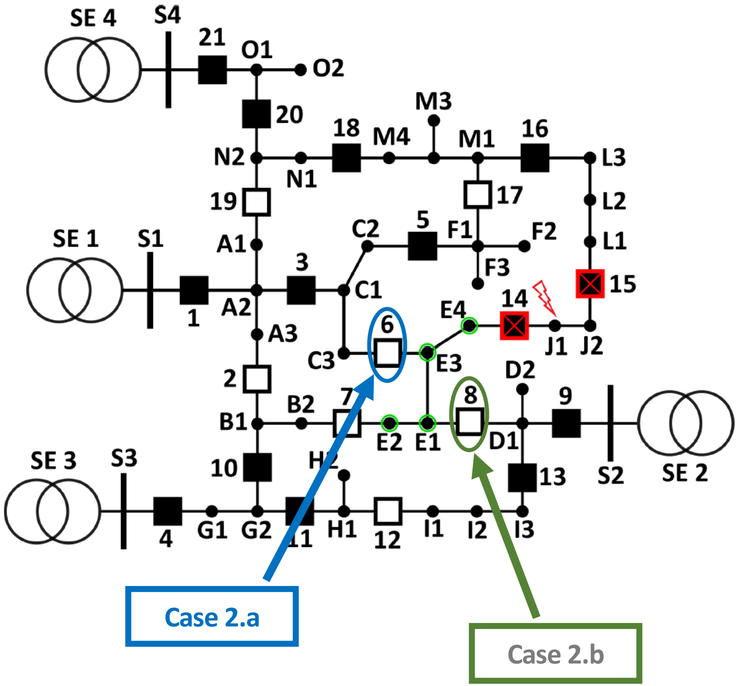


Assessment Cases II

The test evaluates the impact of MCDA inputs to the restoration process



	$w_{P\theta_1}$	$w_{P\theta_2}$	$w_{P\theta_3}$	$w_{\theta_1\theta_2}$	$w_{\theta_1\theta_3}$	$w_{\theta_2\theta_3}$
Test Case 2.a	1/9	1/9	1/9	4	4	1
Test Case 2.b	1	1	1	2	2	2



Smart Grids Plus ERA-Net

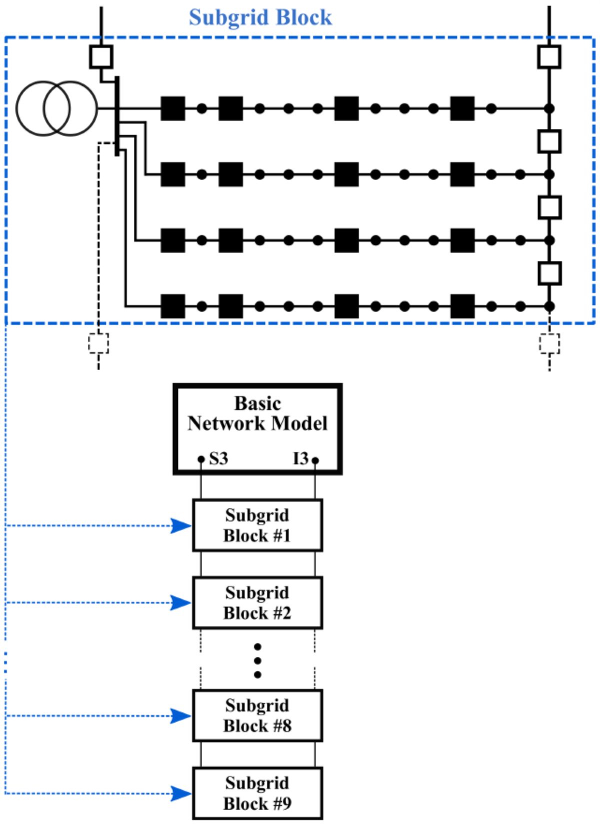
Assessment Cases III

- Test case with 400 nodes grid, to evaluate:
  - The performance of deployed platform
  - The communication latency of the setup
- Each test is repeated 50 times
- Apart from communication with field devices, main delay is due to internal platfrom process

NETWORK LATENCY TO ACTIVATE SR

Number of Nodes	Min	Max	Average	STDEV
40	0.136s	0.192s	0.157s	0.015s
400	1.145s	1.481s	1.319s	0.101s

- The results are in line with update rates between RTU and control center of DSO

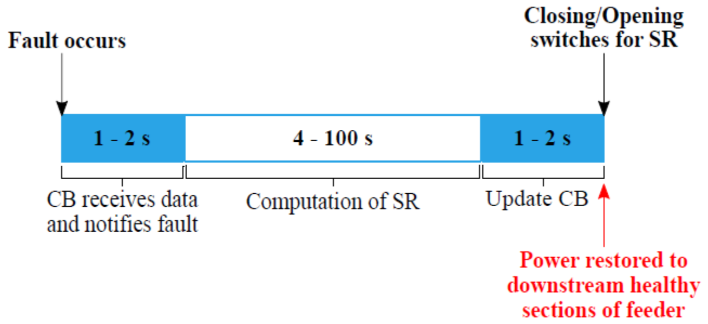


Platform Evaluation

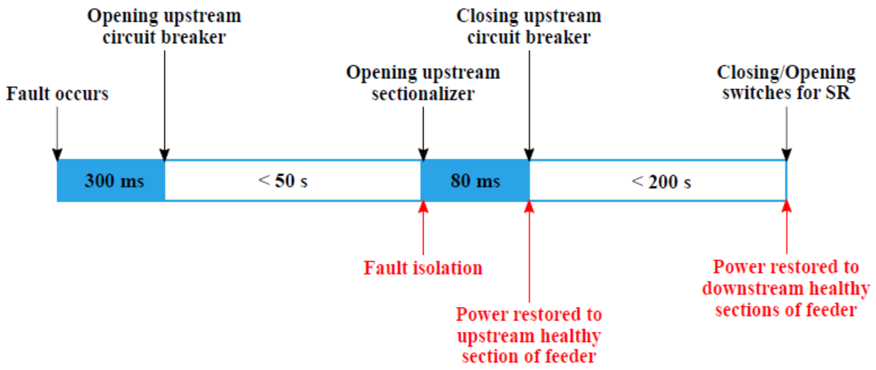
- The computed time starts from the SR activation until the implementation of closing commands for switches

COMPUTATION TIME OF SR IN DIFFERENT TEST CASES

Number of Nodes	Min	Max	Average	STDEV
40	4.846s	5.574s	5.21s	0.013s
400	84.121s	88.78s	86.45s	0.123s



- Operating times are in line with self-healing FLISR solutions (≈ 3 min.) and satisfactory with respect to CAIDI values of European networks (= 40 min., 2016 in Germany)



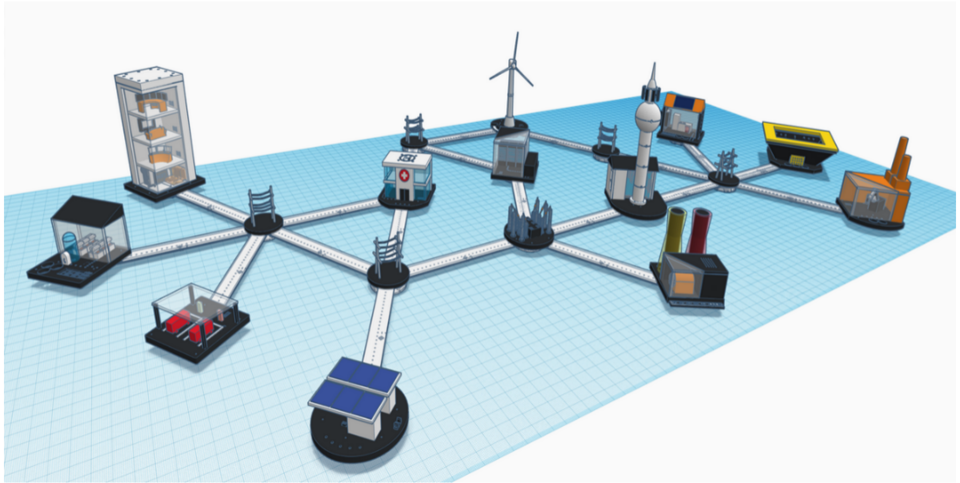
FISMEP Demonstrator

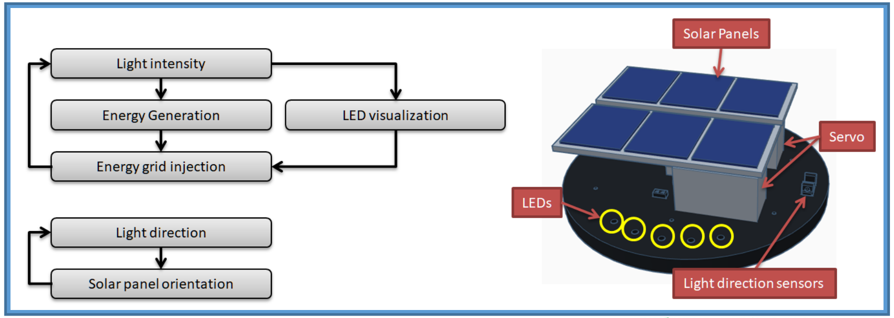
LEGO
Lite Emulator of Grid Operations

FISMEP
FIWARE for Smart Energy Platform

Flexible, reconfigurable, multilayer power platform:

- **Grid:** lower mechanical/electrical layer of branches and nodes
- **Entities:** consume and produce power in the middle application layer:
  - Data Center
  - Stadium
  - Skyscraper
  - EC station
  - Power plant
  - Etc.
- **FIWARE:** upper layer platform, entire coordination via single board computer:
  - IoT Agent / Context Broker / MongoDB
  - MQTT over WiFi



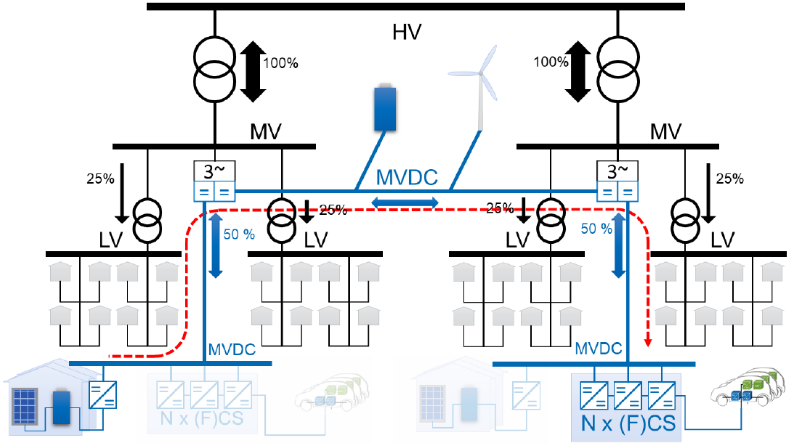


Conclusions and Next Steps…

- FIWARE setup and benefit of the cloud-based properties
- Reusability of components with standardized protocols and interfaces allows to concentrate on grid automation algorithms

Continuous developments:

- Inclusion of a load balancer to distribute the workload in the platform
- Addition of new criteria for the restorazion and new energy system services as middlewares



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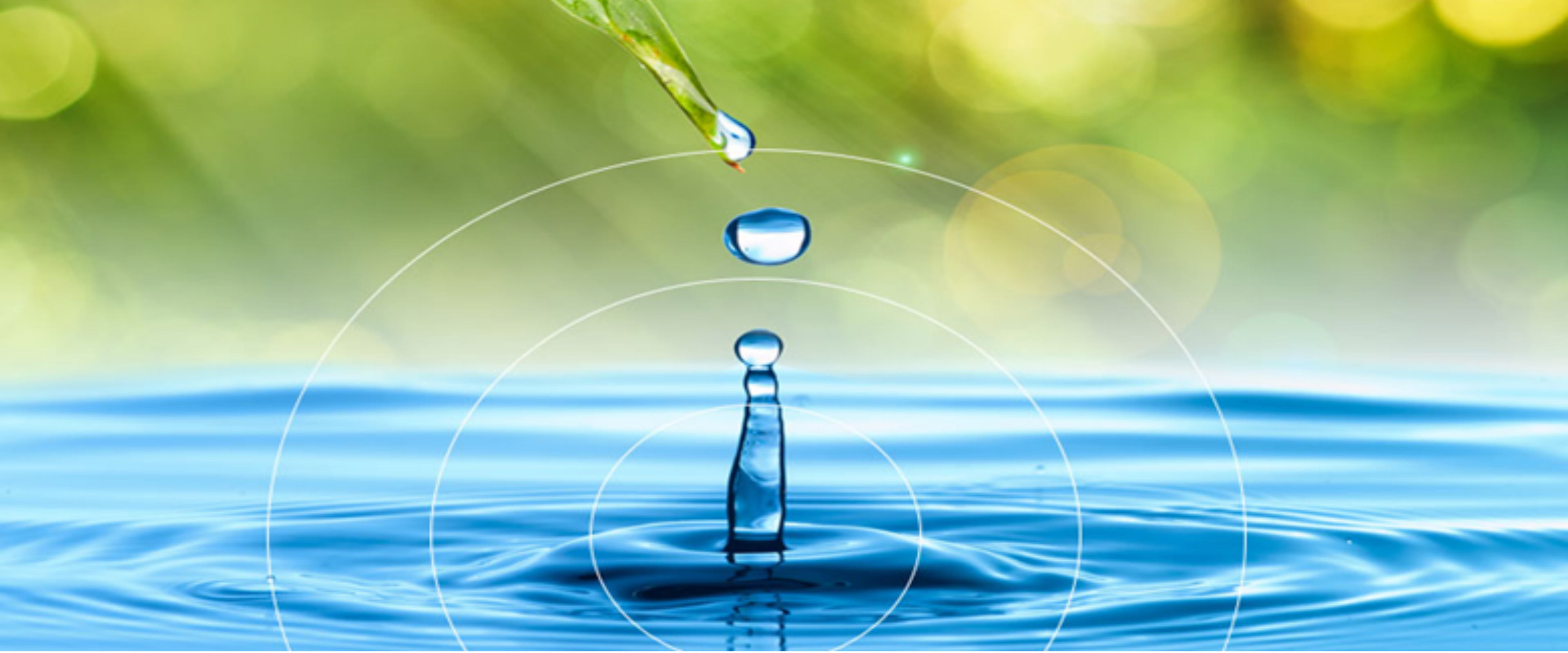

ERA-NET SMART GRIDS PLUS | FROM LOCAL TRIALS TOWARDS A EUROPEAN KNOWLEDGE COMMUNITY

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