HYPERRIDE

THE FUTURE OF POWER DISTRIBUTION

Development and Application of a new Ontology in the Context of Hybrid AC/DC Grids

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ENGINEERING
THE DIGITAL TRANSFORMATION COMPANY

IARIA 2023

15 November 2023, Valencia (Spain)

IARIA

EU H2020 Programme GA No. 957788

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Alessandro Rossi

Short bio

- University Degree in Computer Software Engineering magna cum laude at the "Università degli Studi di Palermo" in 2004.
- Since 2004, researcher at Engineering Ingegneria Informatica S.p.A., team leader in the R&D Laboratory.
- Currently, PM and Technical Manager in several EU co-funded projects.
- Experiences and domains: cultural heritage, digital libraries, emotional interfaces, gamification; since 2010, smart energy: RES, PtG, EMS, BMS, smart buildings, consumption awareness, OPF, LCA, AC/DC grids.
- Currently focused on digital transformation and new enabling technologies: IoT, Cybersecurity, Big Data, Digital Twins, Blockchain.
- 25+ publications of scientific papers to international events and journals.

Hybrid Provision of Energy based on Reliability and Resiliency via Integration of DC Equipment

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Impact and benefits

Project overview

Demonstrations

Project overview

October 1 2020

4 years

European Union Horizon 2020 Research & Innovation Programme under grant agreement No. 957788

Innovation Action
Budget: 7 Million Euros

Objectives:

- Planning, operation and automation solutions
- Development of enabling technologies (MVDC circuit breakers and sensors, DC measurement unit, open ICT platform)
- Fault management and cybersecurity (protection coordination, stability assessment, automatic grid reconfiguration)
- Technology demonstration
- Effective business models & knowledge transfer, recommendations for standardization/ regulation bodies

Project overview

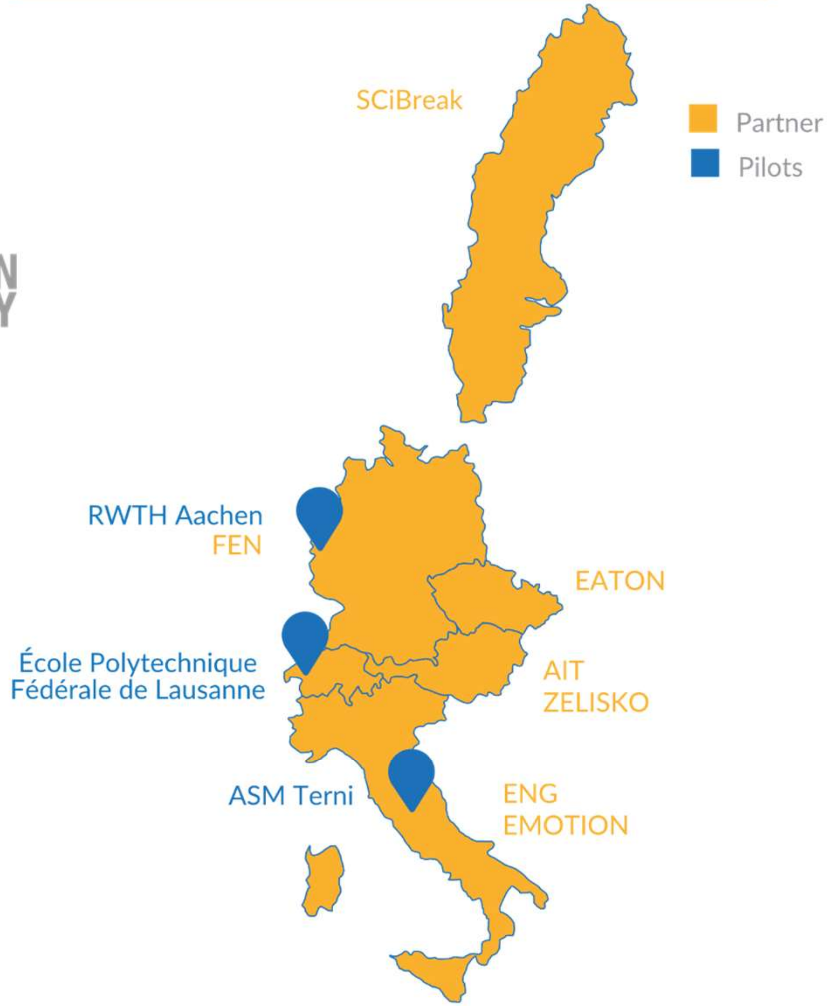
Scibreak

E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

FORSCHUNGSCAMPUS FLEXIBLE ELEKTRISCHE NETZE

EPFL

ASM Terni S.p.A.



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Impact and benefits

Project overview

Demonstrations

Impact and benefits

Provision of guidelines for grid planning and operation strategies of hybrid structures

Automation solutions and algorithms of DC and AC-DC infrastructure

(via open, interoperable ICT platform)

Component solutions will showcase benefits of hybrid infrastructure

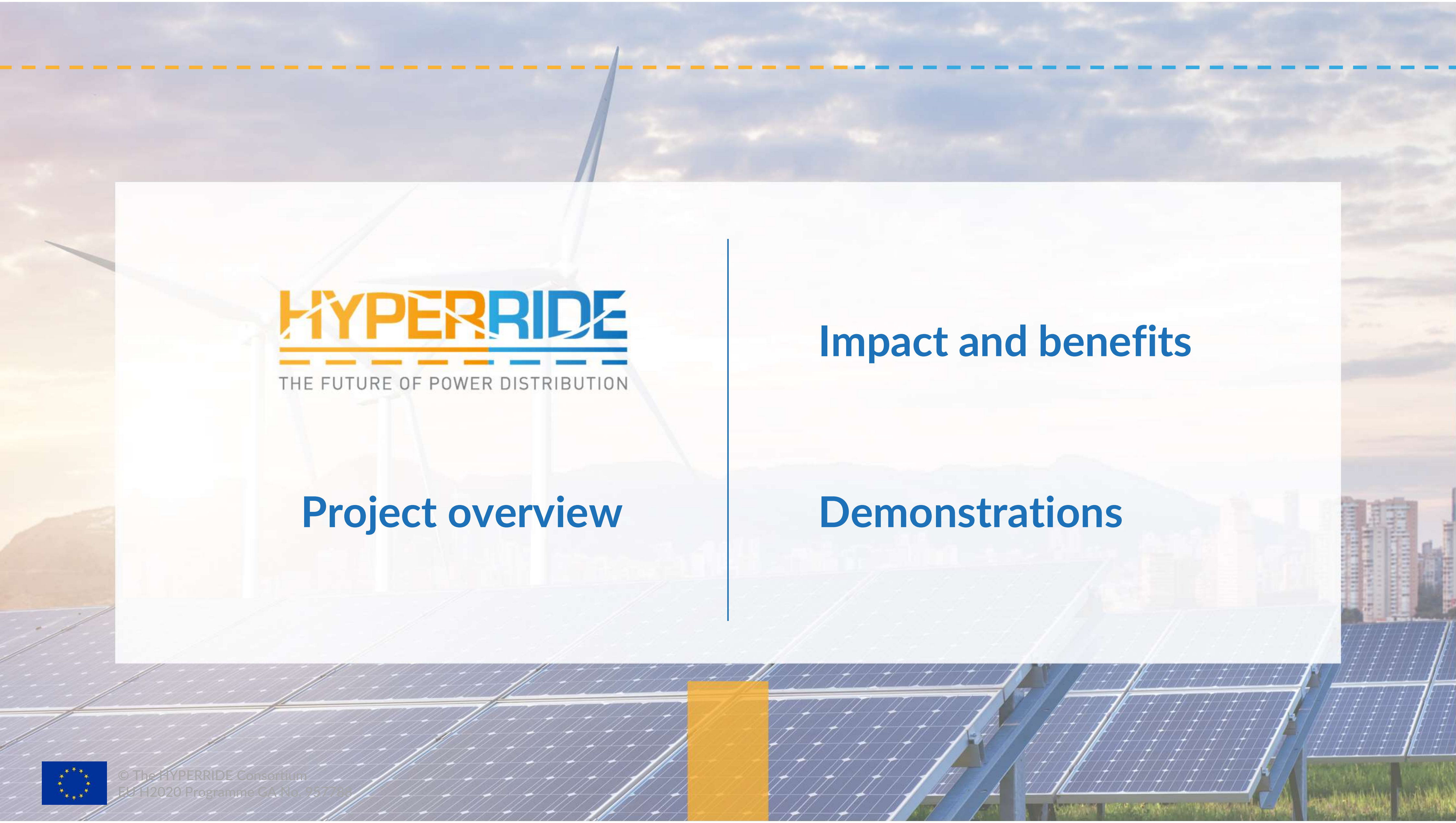
(e.g. MVDC breakers and sensors, DC measurement unit)

Impact and benefits

Safety and security solutions will ensure a resilient energy supply e.g. automatic grid reconfiguration in case of cyberattacks

Provide feedback to enabling technologies based on demonstration experience

Enable business models along the value chain to foster market uptake of AC-DC installations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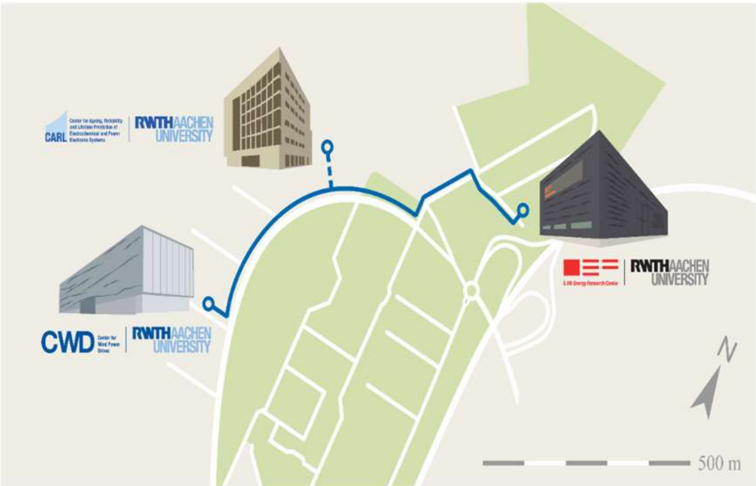
Impact and benefits
Project overview
Demonstrations

Demonstrations

- **Demonstrations in Germany, Switzerland and Italy**
- With demonstrations in three virtually linked countries (Germany, Switzerland and Italy) different application foci are covered with still relevant synergies as a proof of applicability of HYPERRIDE.



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Swiss Pilot

Objectives: testing optimal control strategies for hybrid AC-DC grids as well as adaptive reconfiguration approaches

Interconnection of:

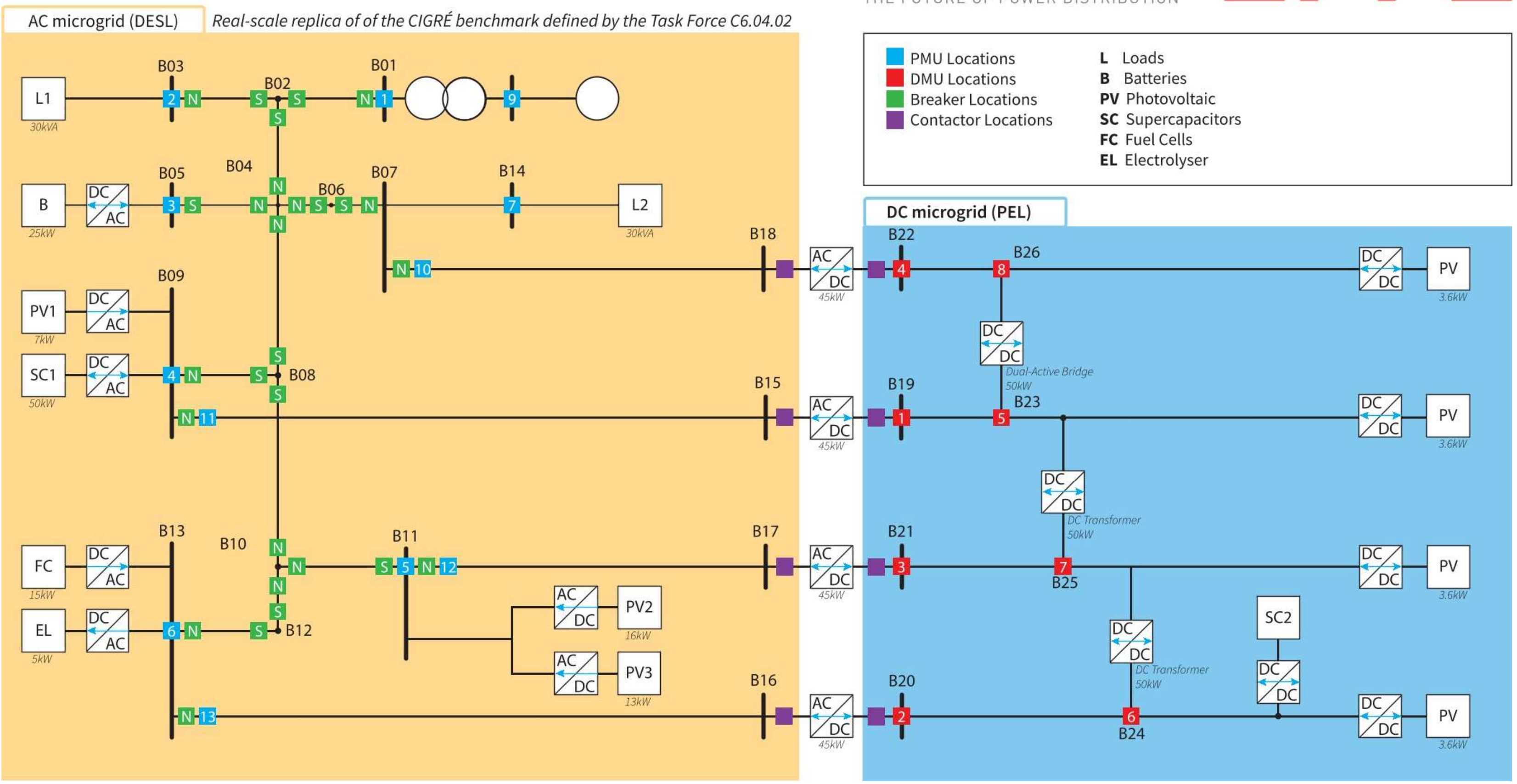
- Distributed Electrical System Laboratory (DESL): CIGRE 15 node LVAC benchmark
- Power Electronics Laboratory (PEL): LVDC (750 V)

Activities for hybrid AC-DC grids:

- Optimal control, including real-scale renewables (PV, EV and heat pumps)
- LVAC applications: PV, BESS, EV-charging, fuel cell, supercapacitor, electrolyzer, hydro oxygen storage, heat pump
- Protection coordination and DC circuit breakers performance
- Local vs. Global grid stability

Swiss Pilot

EPFL Demo: LV Hybrid AC-DC microgrid



German Pilot

Objectives: testing of hybrid MV/LV AC/DC grid architectures using different operation strategies

Interconnection of

- High power MV AC/DC and DC-DC converter
- MV/LV DC-DC converters
- LV AC/DC converters

Activities for hybrid AC-DC grids:

- Demonstration of the software developed for hybrid grid multivendor system operation
- Flexible hybrid grid operation under different scenarios
- Converter and grid stability
- Protection coordination and DC circuit breaker performance
- Coupling of medium voltage and low voltage DC grids

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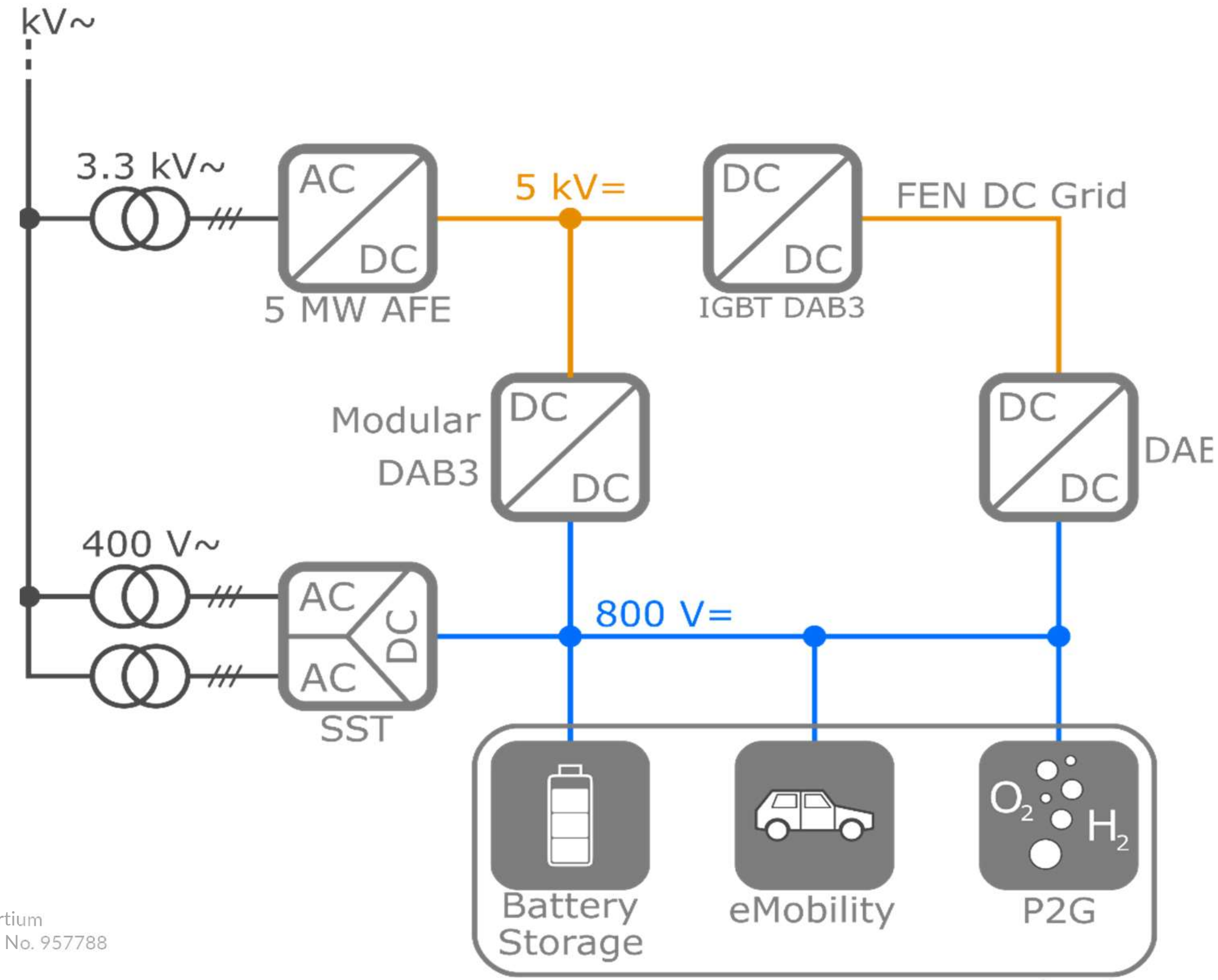
German Pilot



Italian Pilot

Objectives: demonstrating the potential offered by a more modular (cellular) smart hybrid AC-DC decentralized operation of MV/LV electricity grid, with a view to increase grid operation efficiency, reduce reverse power flow towards MV and reduce cyber-security risk.

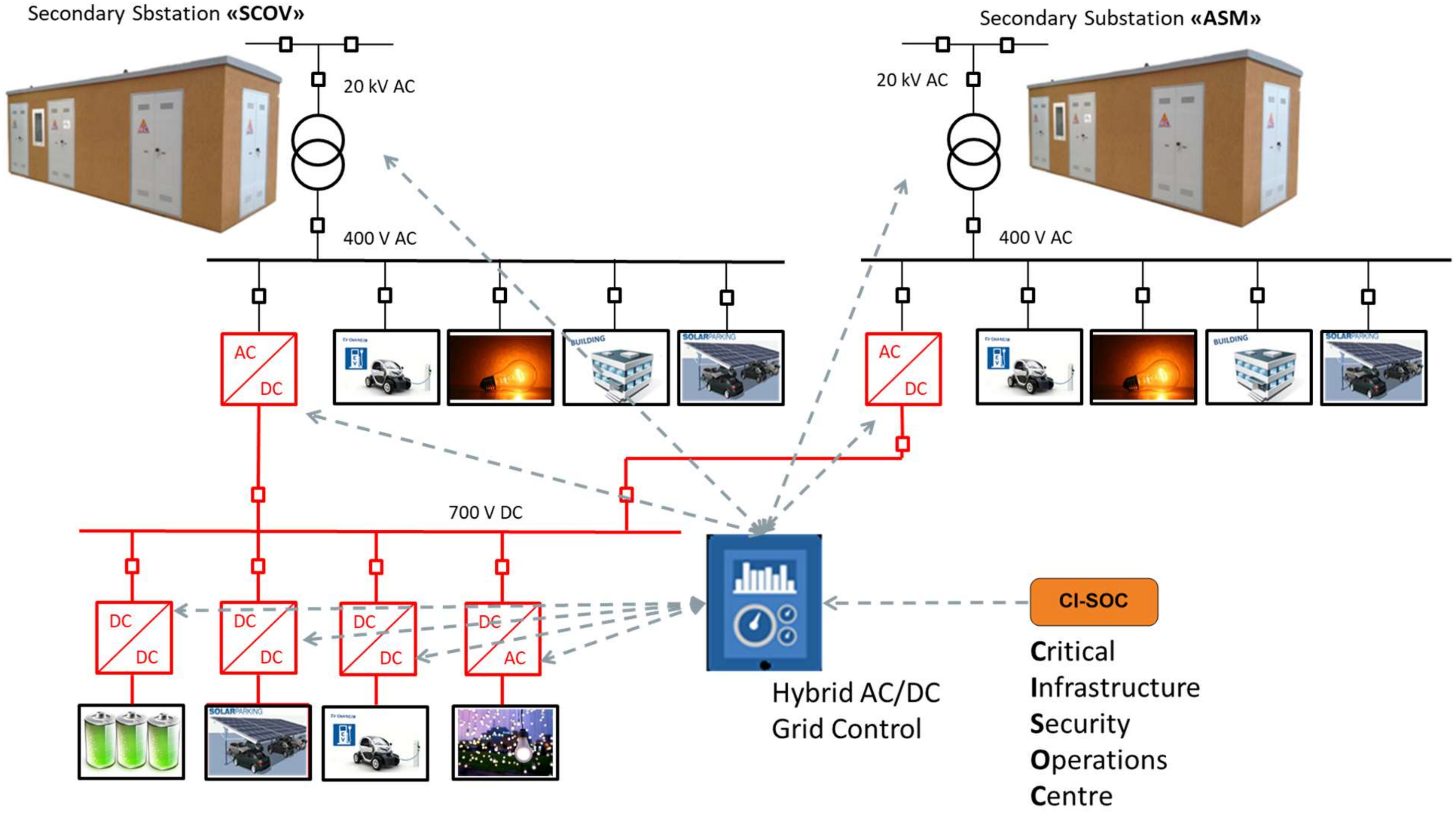
Interconnection of:

- One HV/MV feeder that connects four MV/LV substations
- LVDC interconnection at 700 V
- 350 kW intermittent peak power from PVs generation

Activities for hybrid AC-DC grids:

- Integration of LVDC microgrid in the distribution system, which will connect through DC infrastructure
- Connection of new DC devices: BES, EV, PV, commercial and residential loads
- A new public 40 kW DC electric vehicle charging station, coordinated with the needs of grid operator

Italian Pilot



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Open and secure ICT for modular resilient optimized hybrid grid

EU H2020 Programme GA No. 957788

Aims and Objectives of the ICT Platform

- To define a technology independent **specification of the ICT platform** and tools included
- To develop and test a scalable decentralized **IoT sensing and monitoring** platform
- To integrate cyber-physical sensors to monitor the state of Hybrid AC/DC networks and determine the potential **root causes** of instabilities and failures, for supporting more effective failure **diagnosis and prediction** towards increased security and resilience
- To implement an **interoperable data model** for a Hybrid AC/DC grid
- To provide a common platform for storing and sharing component reliability information as an **open reliability information database**, extending a web-based platform to share data related to failures, and enable aggregate statistics to support system availability and resilience
- To release a **FIWARE-compliant reference implementation** of platform and tools

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Open ICT platform requirements and architecture specification

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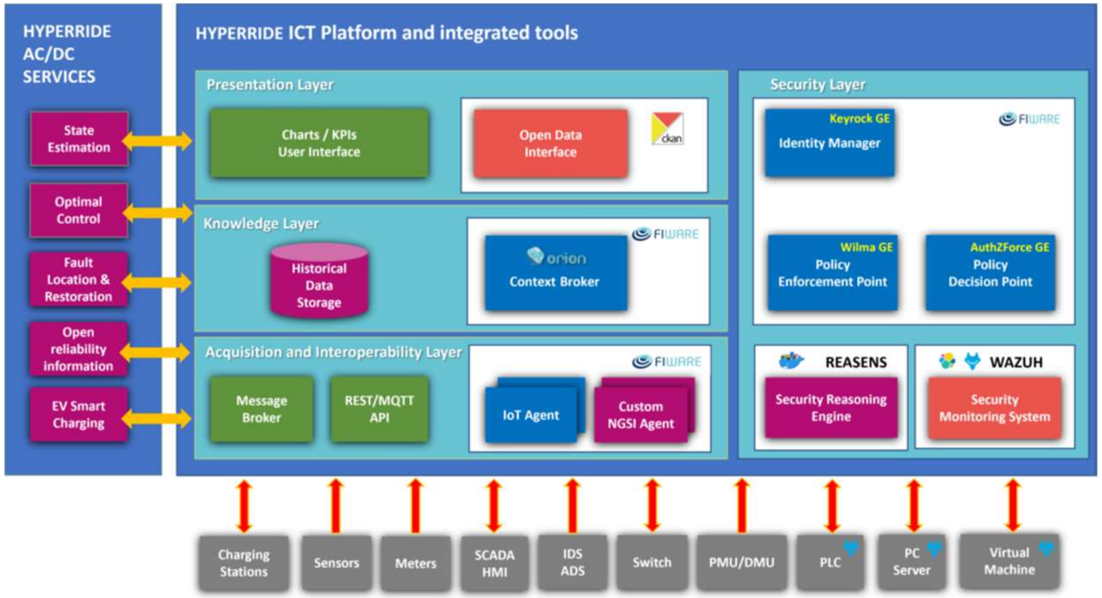
ICT Platform software architecture

- The **Presentation Layer**
- The **Knowledge Layer**
- The **Acquisition and Interoperability Layer**
- A cross-cutting **Security Layer**
- The **HYPERRIDE AC/DC Services**



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Scalable and decentralized hybrid AC/DC oriented sensing and monitoring layer

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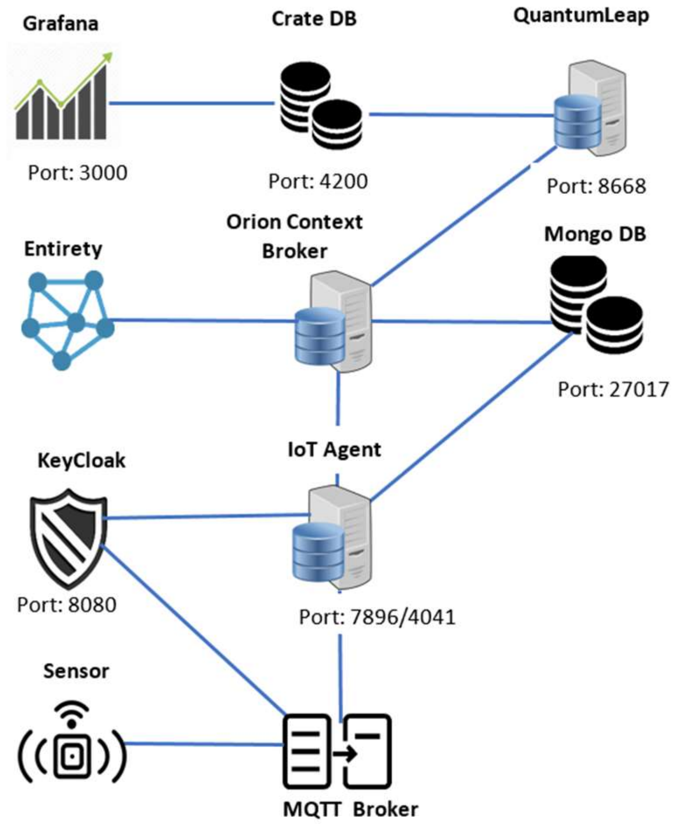
Sensing and Monitoring Layer

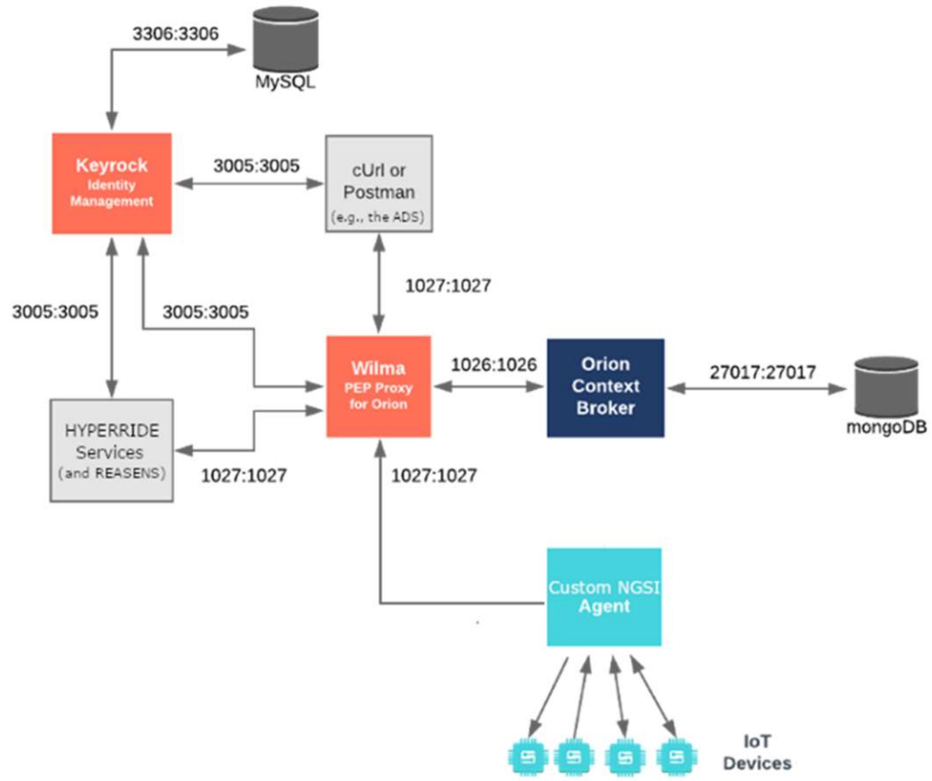
- Deployed and verified at RWTH premises and ENG premises
- Open data: https://github.com/zhiyupan/HYPERRIDE-sensing-and-monitoring-layer
- IoT Integration with Entirety
- Semantic Provisioning and Governing IoT Devices in Smart Energy Domain
- Based on HYPERRIDE data model and ontology
- Entirety dashboard optimised
- Installed and tested in German pilot (FEN grid based RTDS)



Detection and prediction of technical and cyber-contingencies

Security Infrastructure

- FIWARE based Security Layer released
- Integrated into the ICT Plartform (T5.6)
- Cybersecurity, root cause analysis, cascading effect studied
- Keyrock IdM + Wilma PEP Proxy
  - OAuth2 + PDP Level 2
- Secured Orion Context Broker
  - v2 and LD version both supported
- MQTT support: *hyper/test/xds* (HiveMQ topic)
  - Published by ADS and IDS (T5.6 PoC)
  - Subscibed by REASENS, for root cause analysis



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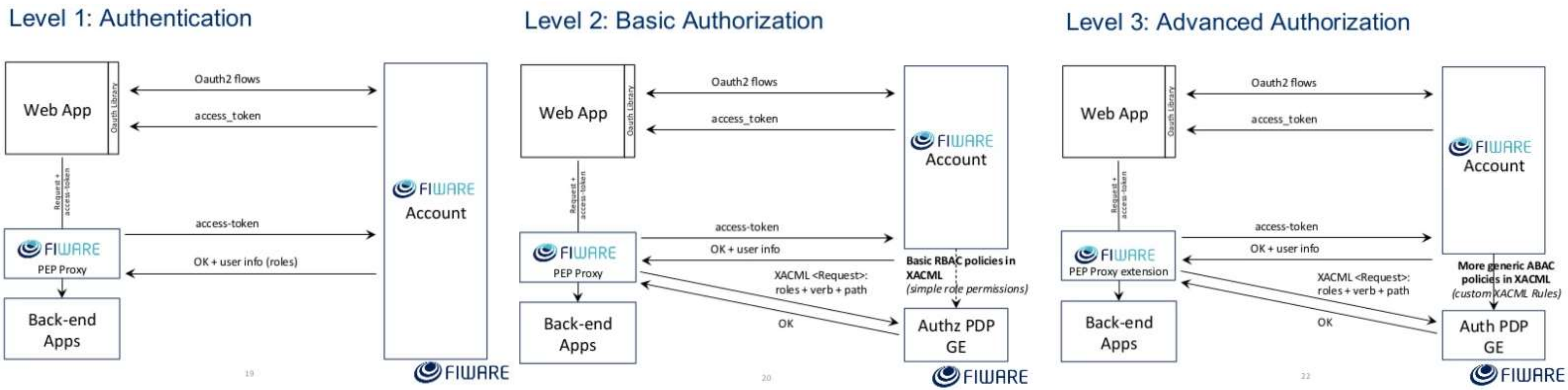
FIWARE Security



In this scenario, the PEP proxy checks authentication with the IdM and forwards the request to the actual resource server (called "Back-end Apps") if security constraints are met.

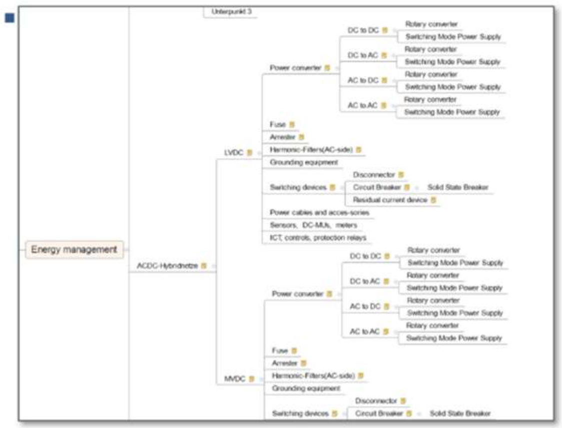
In this scenario, the PEP – after having checked the validity of the access-token with the IdM – makes a consecutive request to the PDP providing the current user's roles and the request details (URL plus the HTTP request method used). The PDP checks this information with its security policies and decides whether access should be granted or not. When defining a permission, which always is part of a specific role, the IdM's user interface simply accepts a URL and a http verb (e.g. GET, POST, PUT, …) that should be granted to all users belonging to the corresponding role. The necessary XACML is created automatically behind the scenes.

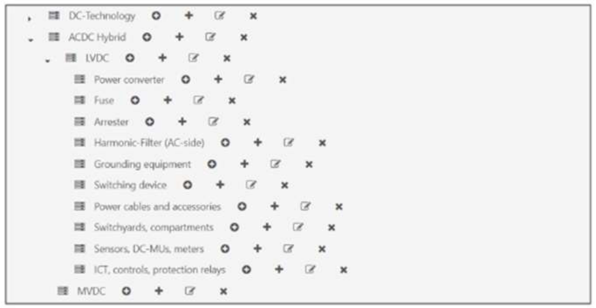
Level 3, however, allows users to write custom rules using XML. Although rules are edited using the IdM web interface, they are required to be stored in the PDP. Thus, every time a user-profile or a role gets updated, the corresponding XACML policies are regenerated and automatically transmitted to the PDP via REST.

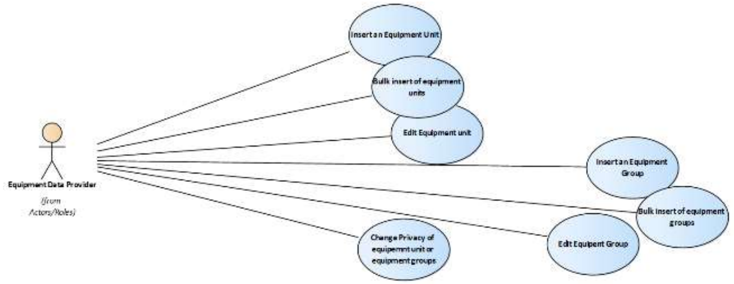
Open reliability information database for components

Open Reliability Database

- Developed a data model for open-source sharing of fault data about AC/DC power systems equipment
- Made extensions to the existing AIT Open Reliability Database to incorporate the types of components considered in Hyperride







Main overall outcome

- First release of the ICT platform released
- Deployed and verified at ENG premises (FIWARE Lab)
- A PoC implemented for test and demo purposes
  - Simulates a simple pilot site with sensors and services
- Documentation for programmers available (GitHub)

Hybrid Provision of Energy based on Reliability and Resiliency by Integration of Dc Equipment

Work Package WP5
Open and secure ICT for modular resilient optimized hybrid grid

Deliverable D5.6
Open HYPERRIDE ICT platform (preliminary version)

Funding Instrument: Innovation Action
Call: H2020-LC-SC3-2020-EC-ES-SCC
Call Topic: LC-SC3-ES-10-2020 - DC – AC/DC hybrid grid for a modular, resilient and high RES share grid development

Project Start: 1 October 2020
Project Duration: 48 months

Beneficiary in Charge: ENG

Document Identifier: doi:10.5281/zenodo.7463225

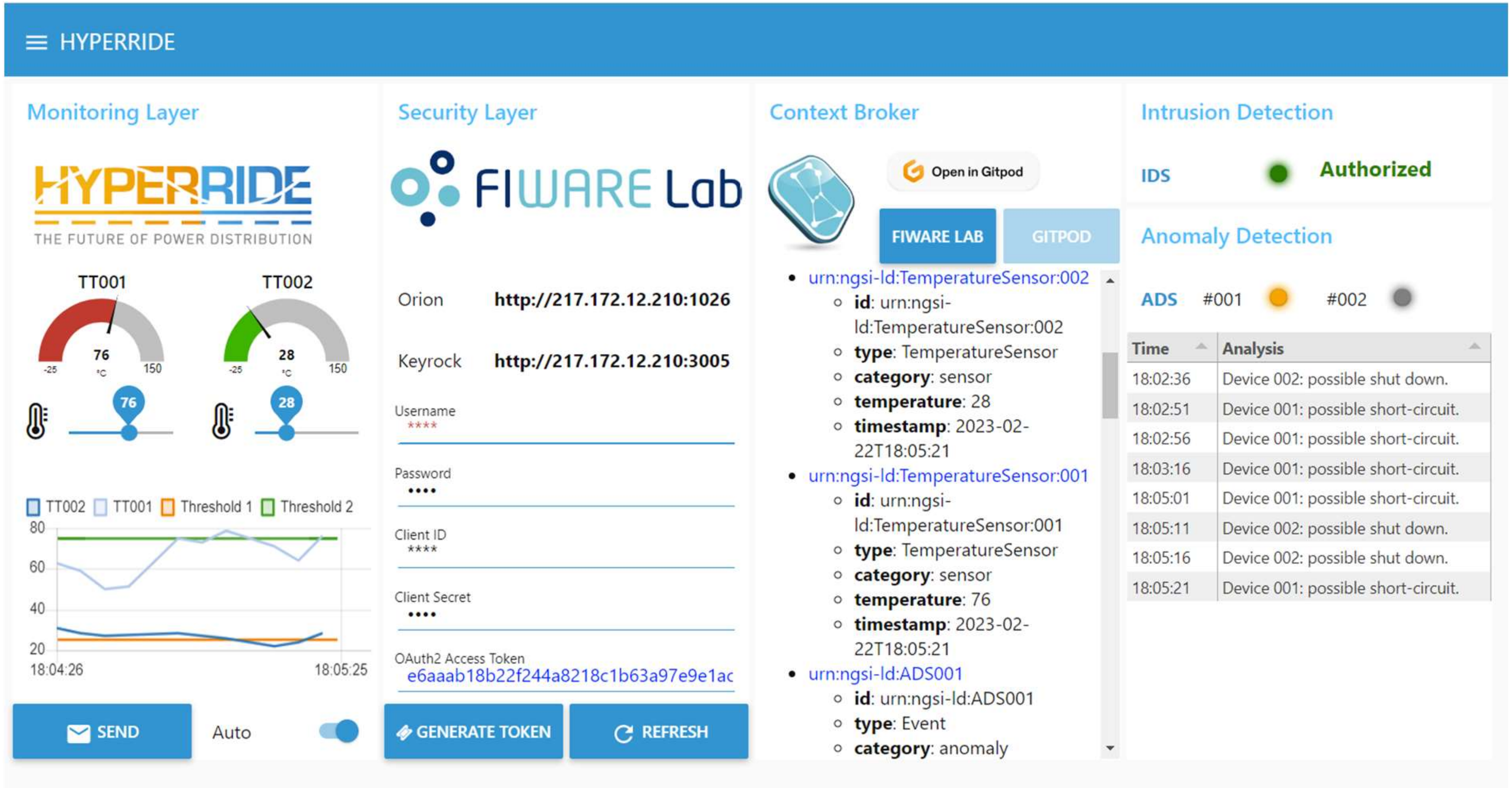
Dissemination Level		
PU	Public	✓
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the Consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 957788.

Open ICT platform adaptation and Evolution

Proof of concept

- Powered by FIWARE app
- ADS + IDS
- Dashboard
- Security data intentionally exposed for test



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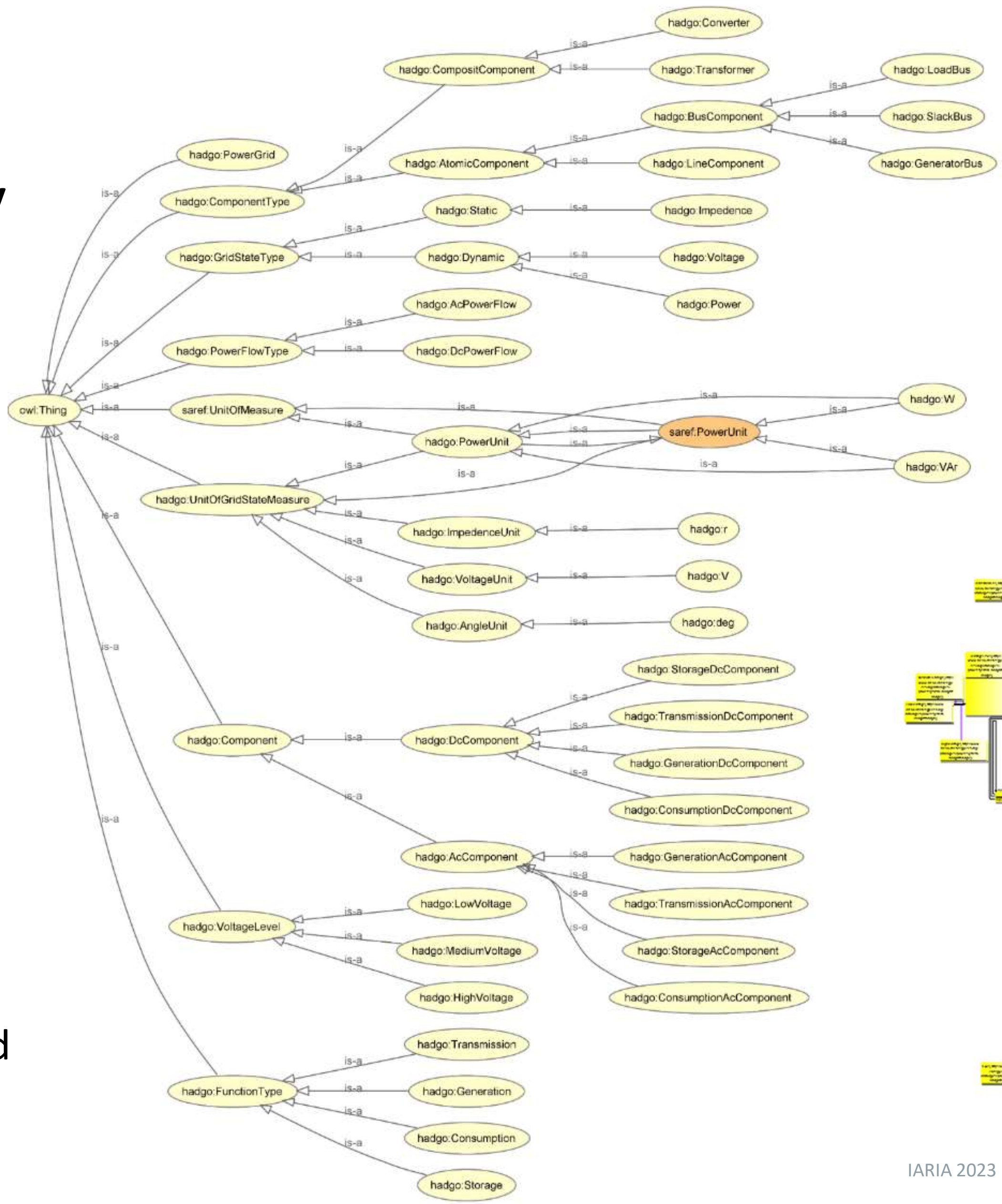
Data model for interoperability

HADGO Ontology

- Ontological realism
- Single inheritance
- Use cases:
  - Power-flow
  - Cascading effect
  - Cybersecurity
  - Etc.
- 50 entity classes
  - SAREF referenced



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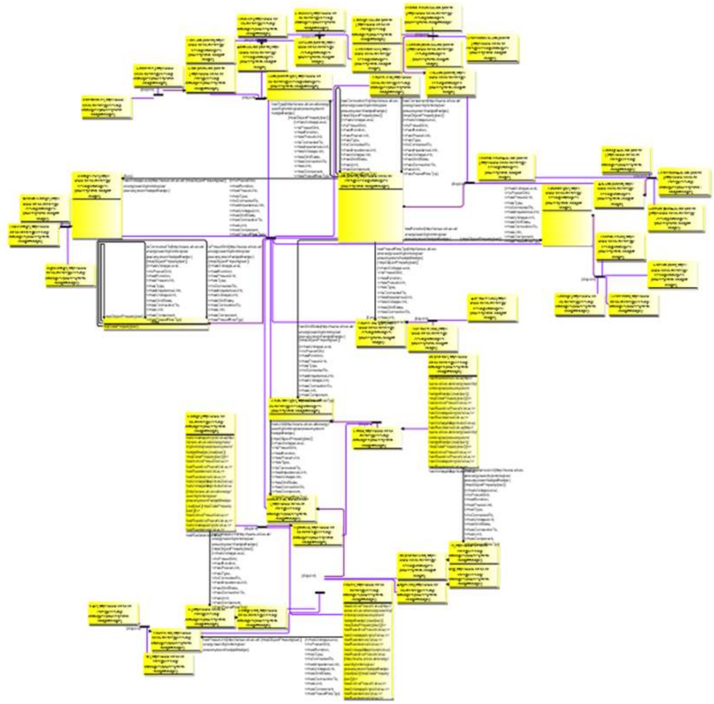
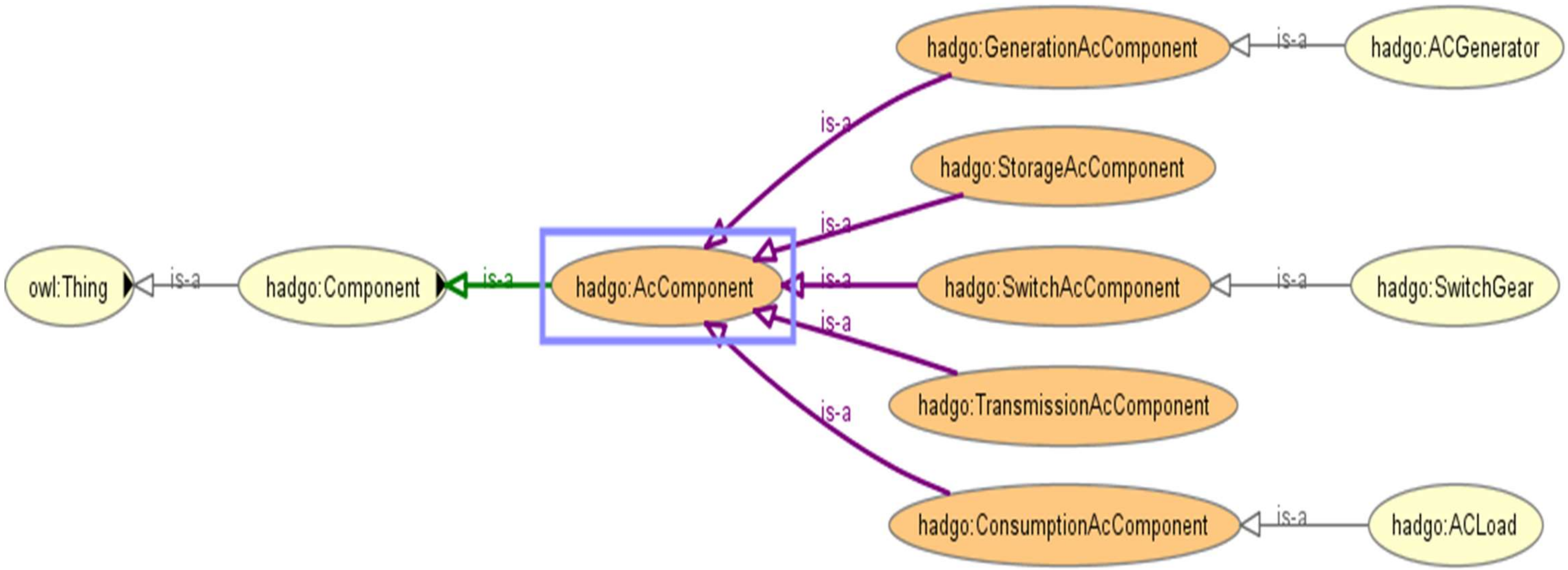
Summary of the ontology's entity classes, data, object properties, and relationships.



HADGO Switchgear Instance Level Modeling



Hadgo Switch Gear Use Case Ontology Hierarchy modeled with Protégé

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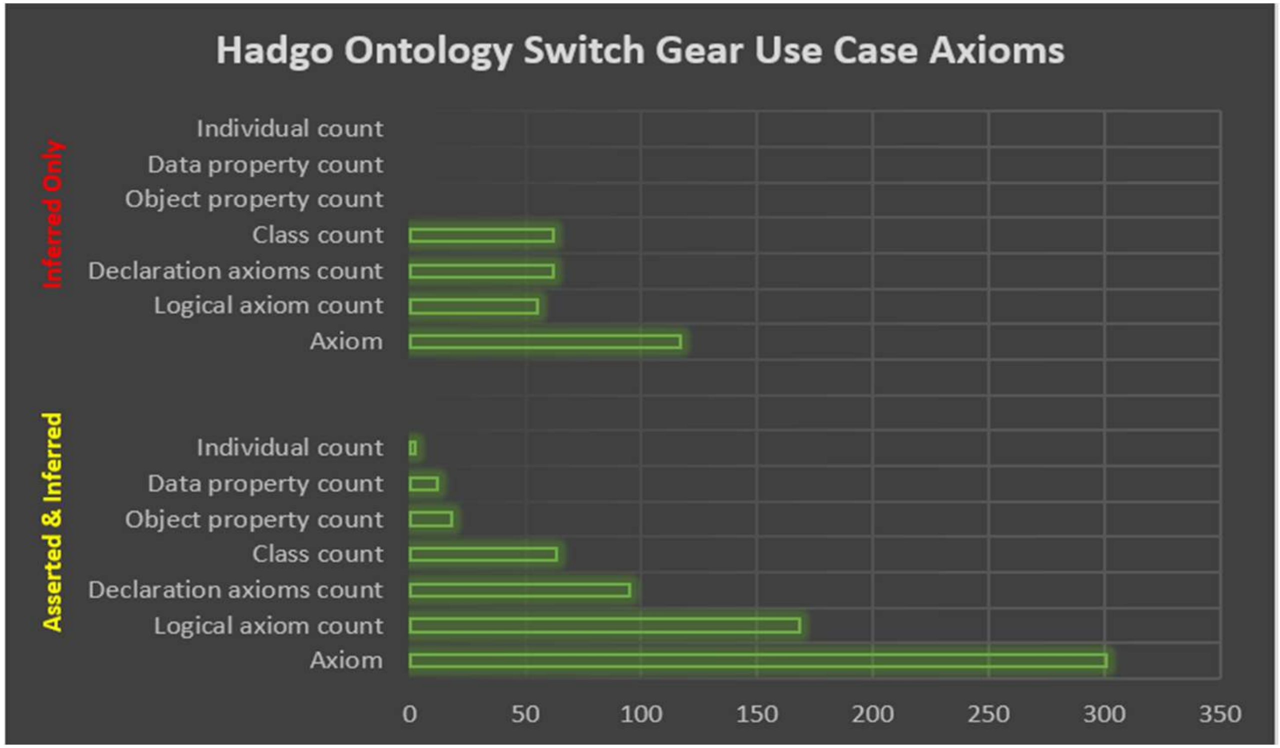
HADGO Switchgear Instance Validation with HermiT

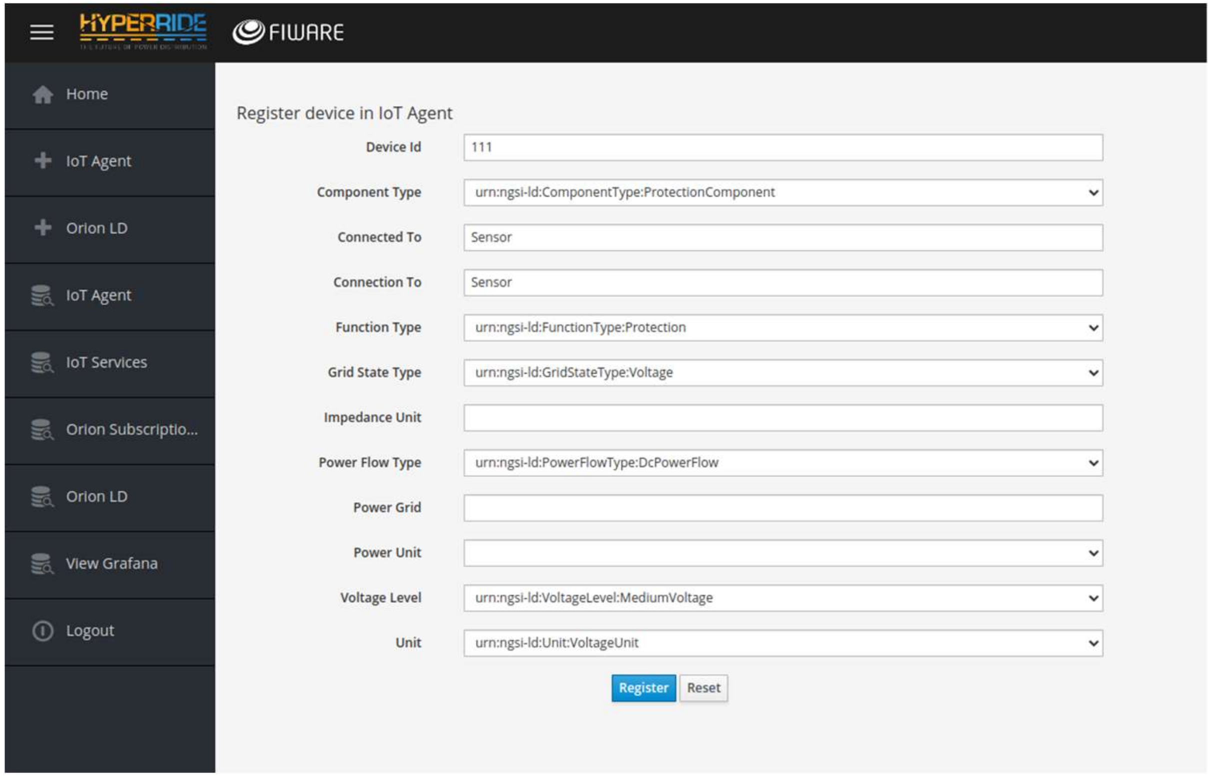
- Total Default Selection Axioms: 301
- Classes Axioms: 62
- Object Properties Axioms: 18
- Data Properties Axioms: 12
- Logical Axiom Count: 55
- Declaration Axiom Count: 62
- Individual Axioms: 2
- Asserted Axioms: 184
- Inferred Axioms: 117



HADGO Ontology Switch Gear Use Case Axioms validated with the HermiT Reasoner

HYPERRIDE Data Sensing and Monitoring Layer

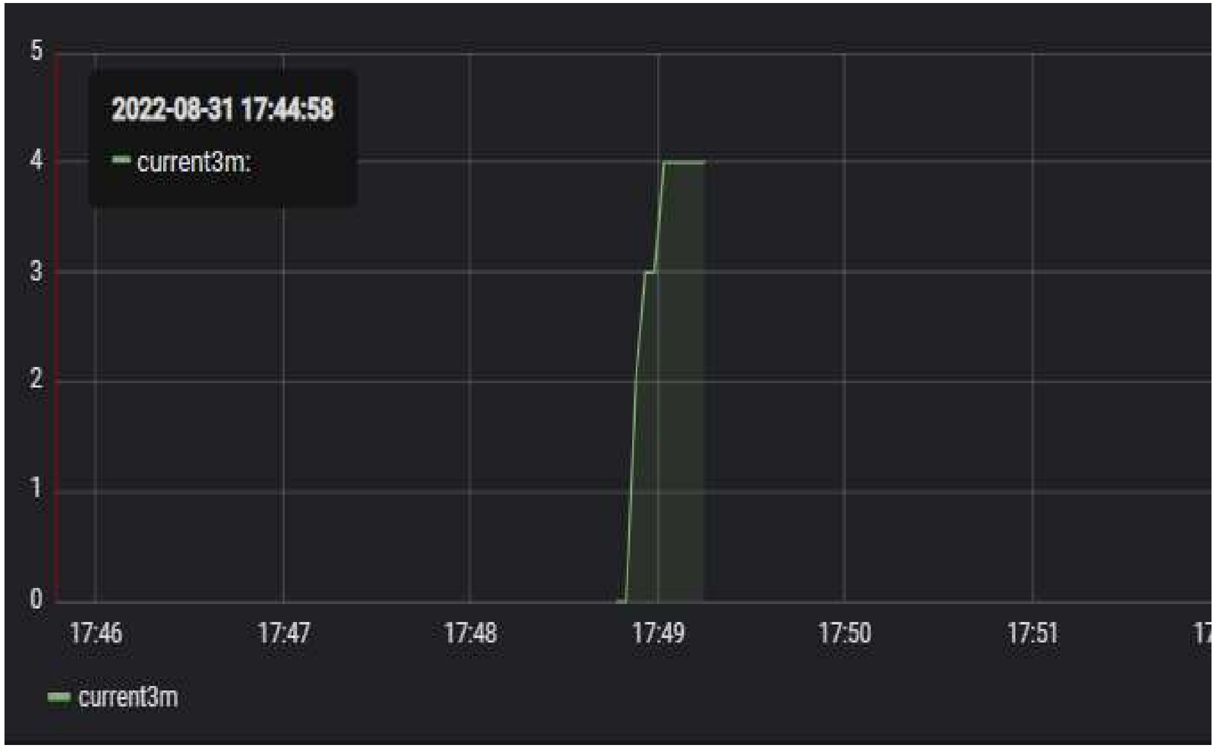
- Data Provisioning
- Data Modeling
- Data Harmonization
- Data Persistence and Storage
- Semantic Interoperability
- Context Broker
- Service Group
- Ontology Integrator



Entirety Data Management Application Powered by The Fiware Platform

RealTime Visualization of Grid Entities with Grafana

- Main contactors & Schaltbau CT1230/08 + CT1130/08
- Current sensors & LEM LF 1010-S current transducer
- Voltage sensors & LEM DVM 3000 voltage transducer
- Controller & WAGO 750 Series Modbus Bus-coupler



HADGO Ontology Switch Gear sub component data generated and monitored with Graphana

Conclusions and Future Work

- HADGO ontology is a proposed core reference ontology for the AC/DC and DC smart grid.
- The UML information modeling for the software applications implementation was carried out with Enterprise Architect while the ontology modeling was implemented with Protégé.
- The HADGO ontology was validated using the HermiT Reasoner and 301 asserted and inferred axioms were achieved in this experimental development.
- Use of data driven approach to scale the updating of the HADGO ontology.
- The implementation of a SPARQL query portal for update/query of axioms on the HADGO ontology.
- The implementation of an algorithm for the alignment of SARGON and HADGO ontology.

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Q&A

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Thank you

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November 13-17, 2023, Valencia, Spain

Conclusions (at project level)

- Overall work in line with the (amended) scheduling
- Four deliverables, D5.2, D5.3, D5.4 and D5.6, released on time
- All expected software releases publicly available + documentation
- The ICT platform integrates the outcomes from the other tasks
- The PoC tests and demostrates the ICT platform functionalities
- Ready to be deployed at pilot site
- Continuous interaction with pilot managers and other WPs also in the next months

Next Steps (at project level)

- Evaluation of the sensing and monitoring layer with real grid measurement
- Integration of REASENS into FIWARE and development of the reasoning model (Evidential Network)
- Verification of the HADGO at pilot site for possible refinement of data model and ontology
- Populate the reliability database with information regarding the equipment being used in the project
- Adaptation, deployment and refinement of the ICT Platform at ASM pilot site
  - Eaton SG4250 controller selected as central control and monitoring interface
- Bug fixing and feature request management
  - WP4 service (State Estimation, Service Restoration) may be adapted and tested
- Start pentest campaign (D5.7) and implementation of feedbacks (D5.8)

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