This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 774145

Leveraging Networked Data for the Digital Electricity Grid

The Net2DG Project

Research Report

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77th Meeting of the IFIP 10.4 WG – Reggio Calabria, Italy, 28-31- January 2020

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Project Facts

- **Call/Topic: H2020-LCE-01-2016-2017**

(COMPETITIVE LOW-CARBON ENERGY).

Next generation innovative technologies enabling smart grids, storage and energy system integration with increasing share of renewables: distribution network

Type of action: Research and Innovation Action
Start Date: 01.01.2018
End Date: 30.06.2021
Duration: 42 months
EU Funding (total cost): 3,591,872.00EUR

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Consortium

8 Partners from 4 European Countries

Aalborg Universitet	Denmark	Academia
Technische Universitaet Wien	Austria	Academia
GridData GmbH	Germany	Industry
ResilTech SRL	Italy	Industry
Fronius International GMBH	Austria	Industry
Kamstrup AS	Denmark	Industry
Stadt Landau A.D. Isar	Germany	Industry
Thy-Mors Energi Service A/S	Denmark	Industry

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Project Overview

Goals: enable and develop novel Low Voltage (LV) *grid observability applications* and Novel *control coordination approaches* for

- voltage quality,
- grid operation efficiency,
- LV grid outage diagnosis.

Expected Results: proof-of-concept solution based on OTS computing HW and available communication technologies

Strategy: correlating measurement data from

- smart meters
- smart inverters

with information from

- Distribution System Operator (DSO) subsystems

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Net2DG Targets

The Net2DG solution will allow regional DSOs the

- reduction **of time to outage diagnosis** by 70%
- reduction of **grid-losses** in the LV grid by 10%
- anticipation and mitigation of 60% of the upcoming **voltage quality problems**.
- reduction of **LV grid reinforcement investments** for increased hosting of DER by 30%
  - (in comparison to the currently used worst case planning methods).

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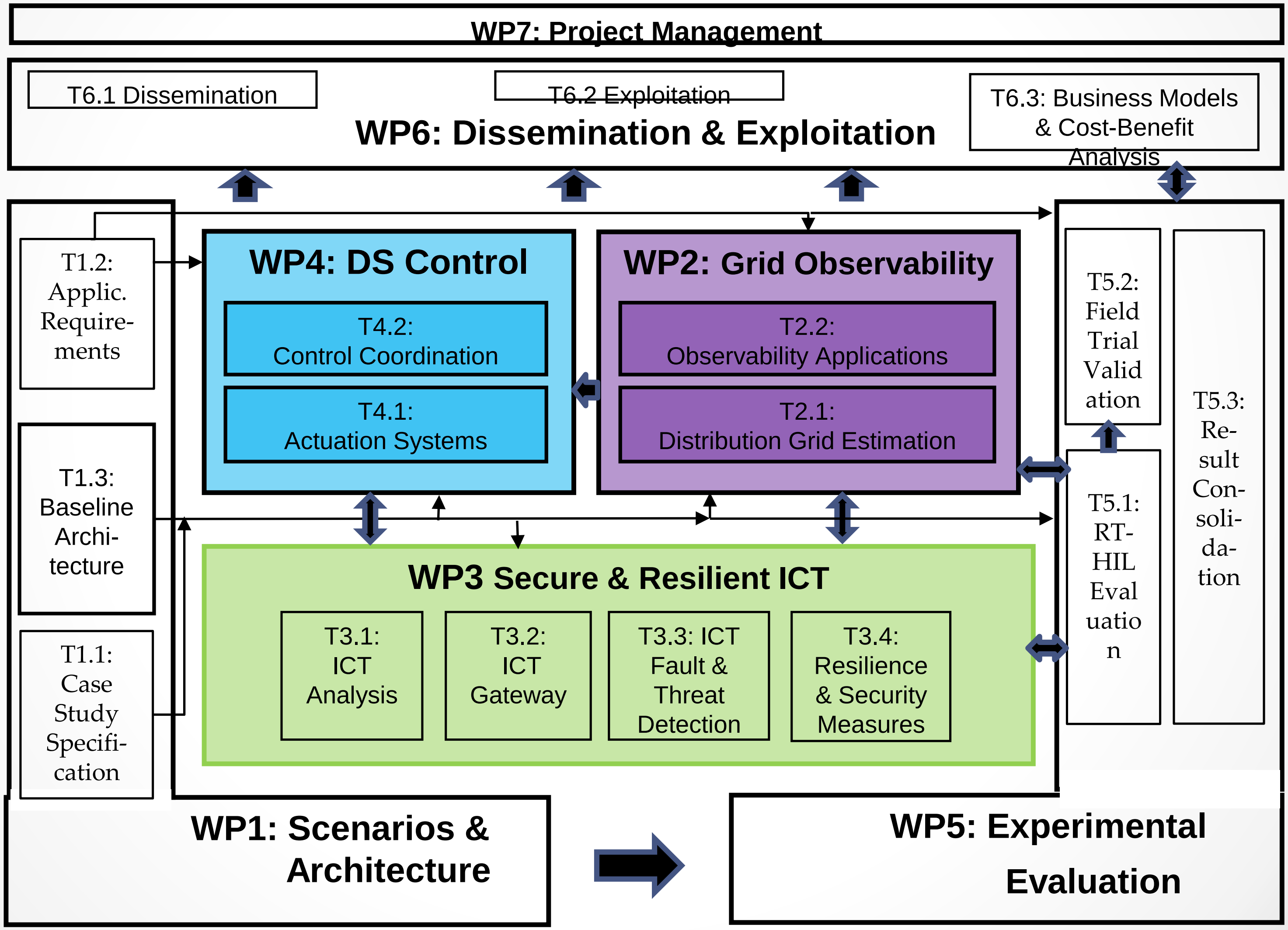
Net2DG Work Structure



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understanding system behaviour

….. by analyzing the low voltage grid from three different angles:

- Understanding what creates **outages** in the low voltage grid.
- Understanding of **barriers** for achieving **operational efficiency** in the low voltage grid operation.
- Understanding what conditions create **problems** in **delivering optimal voltage quality** to end-consumer.

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Definition and prioritization of a set of 12 use-cases

….based on concrete problems and interest from the two DSOs in the consortium and from the 11 reference group members - DSOs and DSO organizations in Austria, Germany, and Denmark.

1. Outage Detection
2. Outage Diagnosis
3. Preventive Maintanence
4. Neutral fault detection
5. Neutral fault diagnosis and location
6. LV Grid Monitoring
7. Automatic Voltage Regulation
8. Loss Calculation and Recording
9. Loss Minimasation through grid reconfiguration
10. Loss Minimisation using interaction with flexible energy resources
11. Calculate and Visualize energy/power exchange in interconnection points to TS and overall in DS grid
12. Recommend improvements to the DS grid to minimise energy exchange from TS grid

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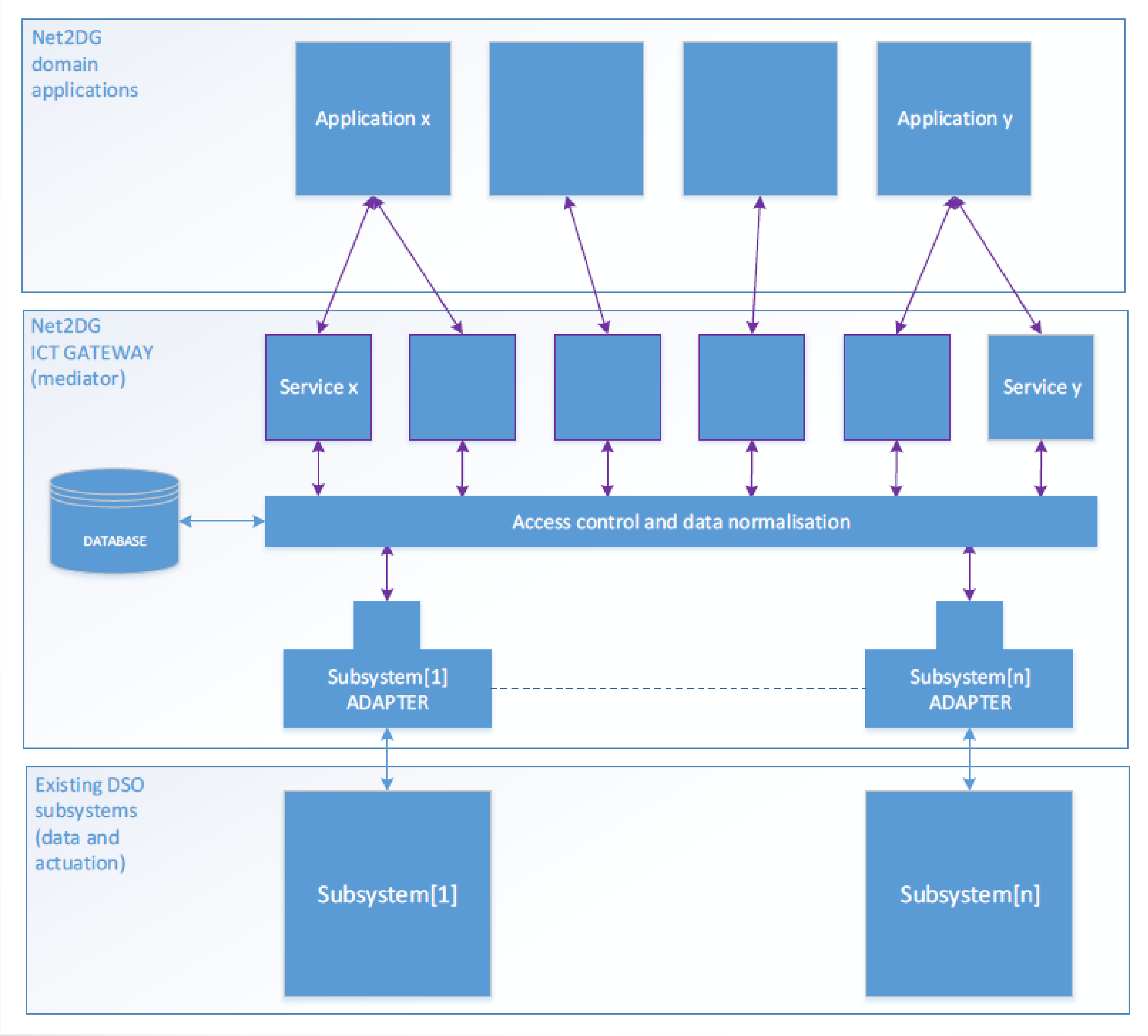
High Level Architecture



- We have established the **system architecture** and its basic constructions for **subsystem interaction**
- It is based on sound principles from **system-of-systems** and can fit into an existing system landscape for a small or medium sized DSO in the European setup.

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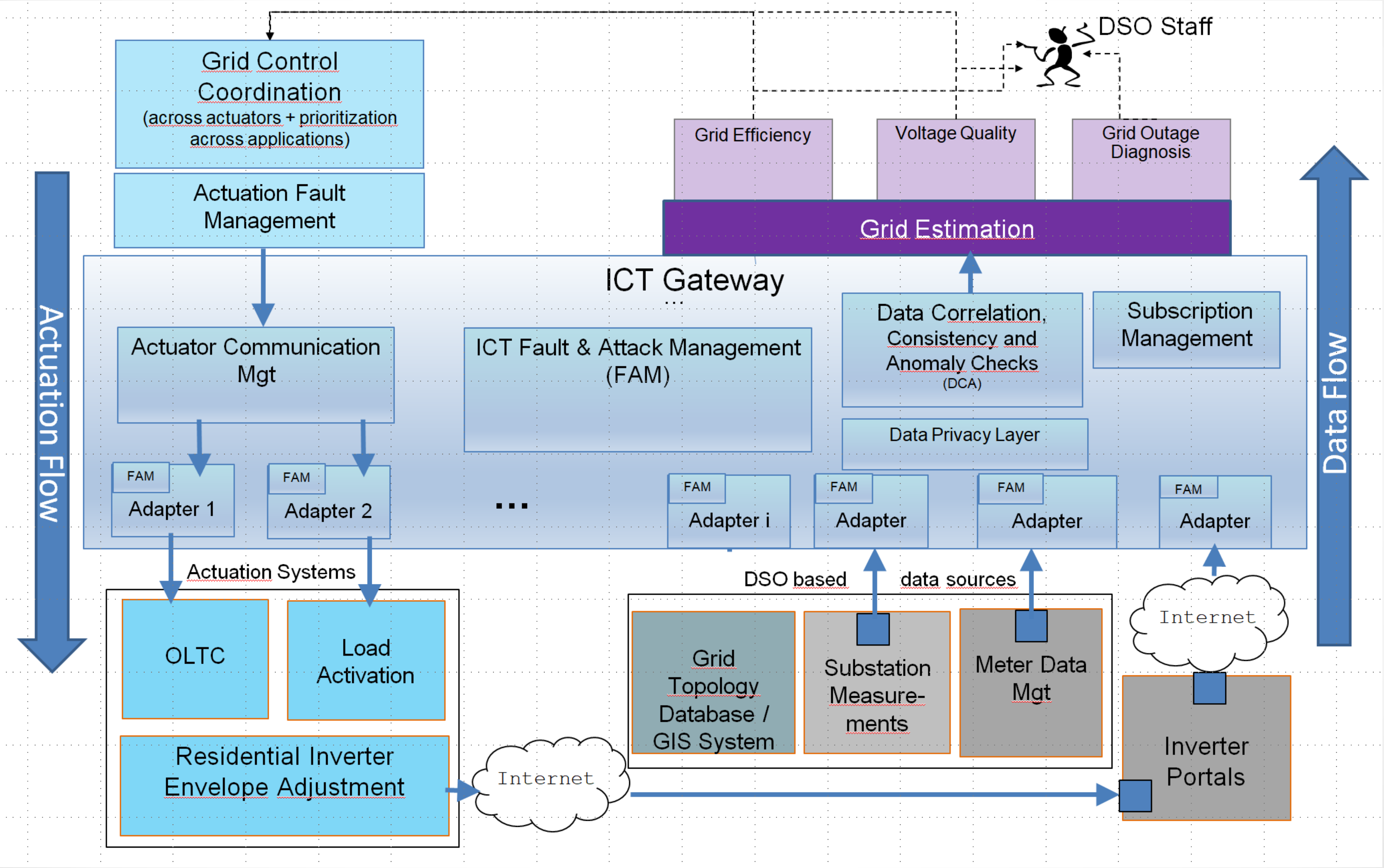
More Refined Architecture



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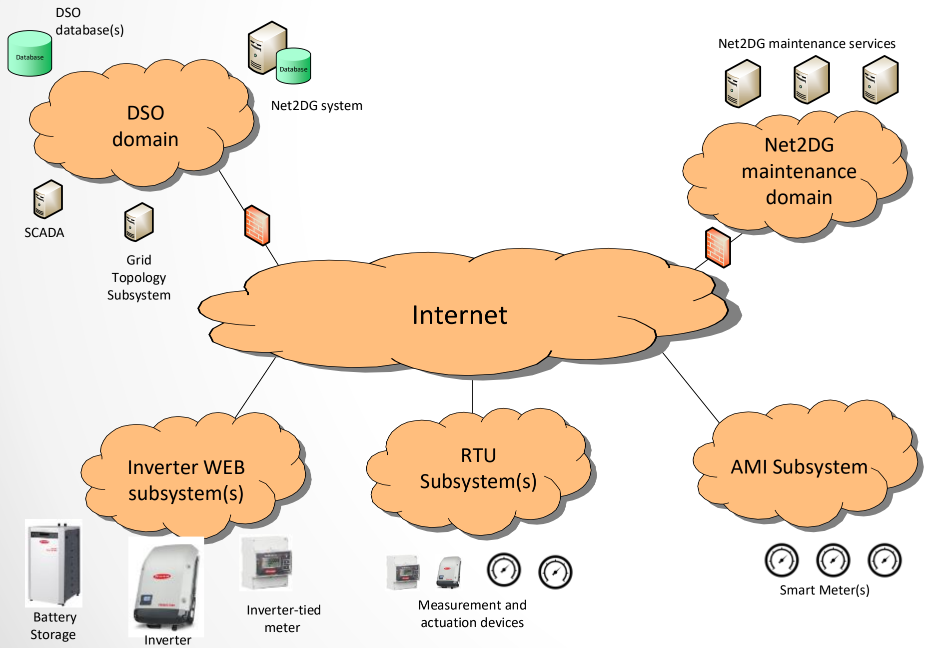
ICT Analysis

- Identification and analysis of **communication technologies**
- Identification and description of **subsystems' interfaces**



SW	SW to ICT GW	ICT GW to SW
Subscribe(type[x])	list of end devices; DER control commands	monitoring data, status information and alarms
Publish	monitoring data, status information and alarms	changes to the end device list, changes of DER control commands
Get(order(x))	request device capabilities, end device list, grouping assignments of inverters, der control commands (default values, events, curves) for groups	N/A
HTTP PUT	send inverter specific status, capability, settings, availability	N/A
Reply(status,[result])	HTTP 200,..	HTTP 200,..
Data for		

System AMI HE to ICT GW	ICT GW to HE	HE to ICT GW
Request-Reply(	Request(logger[x])	Reply(logger[x])
Publish	N/A	Send logger upon request
AsyncRequest(order(x))	Request for asynchronous execution of order(x)	OK or Not-OK
SyncRequest(order(x)	Request for synchronous execution of order(x)	OK or Not-OK
Reply(status, [result])	Reply from order request, in case of asynchronous request, it contains a status on the acceptance of the order request (OK/Not-OK). For the synchronous request, it contains an execution status and optionally an order result.	

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ICT Analysis

- Identification of **information** each subsystem is able to provide
  - e.g., *measures*, *events*, *alarms*, *topological* grid information

AMI - List of measures

AMI HE to ICT GW	Specification
Voltage Quality	Phase, event, mean/max/min. value
Load Profile	Active & Reactive energy
Power Quality	Frequency counter, voltage variation ±10%, rapid voltage changes, power interrupts, voltage dips and swells, voltage THD L1 to L3, current THD L1 to L3.

AMI - List of alarms

AMI HE to ICT GW	Description
Over voltage L1 to L3	Set if overvoltage on phase
Under voltager L1 to L3	Set if undervoltage on phase
Missing phase fault L1 to L3	Set if phase is missing
Phase Voltage sequence	Set if phase voltage sequence is reversed
Earth Fault	Set if earth fault is detected
Magnetic detection	Set if magnetic field is detected - Tampering
ReversePhaseCurrent L1 to L3	Set if reverse current is detected on phase
VoltageAsymmetryStatus	Set if voltage asymmetry is above 2%
Power fail	Set if power fail is registered
NoPhaseCurrent L1 to L3	Set if no current is registered on phase

Inverter SW - List of alarms and status information

SW to ICT GW	parameter	description	resolution
Alarms	Over Current	Out of boundaries depending on the country regulations	Posted as they occur
	Over Voltage		
	Under Voltage		
	Over Frequency		
	Under Frequency		
	Voltage Imbalance	Asymmetric voltage in the grid	
	Low Input Power	To be defined	
Status Information	Operational State	To be defined, most likely: standby Inverter is off Inverter is shutting down Inverter starting Inverter working normally Power reduction is active One or more faults present Inverter is currently being updated	To be defined
	Connection Status	No communication possible	

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ICT Analysis

- **Analysis** of **Data Volume** on interfaces of ICT Gateway
  - 4 cases for the analysis:
    - Case 1.1: field test case A (~100 households for Landau)
    - Case 1.2: field test case B (~2000 household for TME, potential largest extent of field trial)
    - Case 2: full TME grid (~50.000 households)
    - Case 3: full scale, a large medium sized DSO level (~500.000 households)

Estimation of total data volume per day for the various cases

Case	AMI	Inverter web	Inverter Modbus	Stationary PQ	Streetlight	Grid topology	Total
1.1	382kB	7MB	3.5MB	50kB	4.8kB	37.5kB	11MB
1.2	7.6MB	21MB	10.5MB	1MB	96kB	22.5MB	62.7MB
2 (Land)	191MB	526MB	263MB	5MB	2.4MB	18.75MB	1GB
2 (TME)	191MB	526MB	263MB	5MB	2.4MB	0.5GB	1.5GB
3 (Land)	1.9GB	7.8GB	3.9GB	50MB	24MB	187.5MB	13.9GB
3 (TME)	1.9GB	7.8GB	3.9GB	50MB	24MB	5GB	18.7GB

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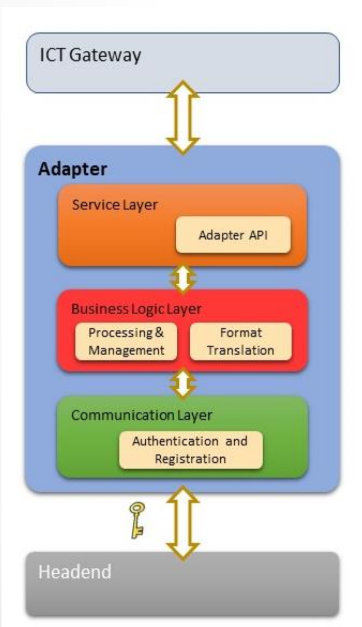
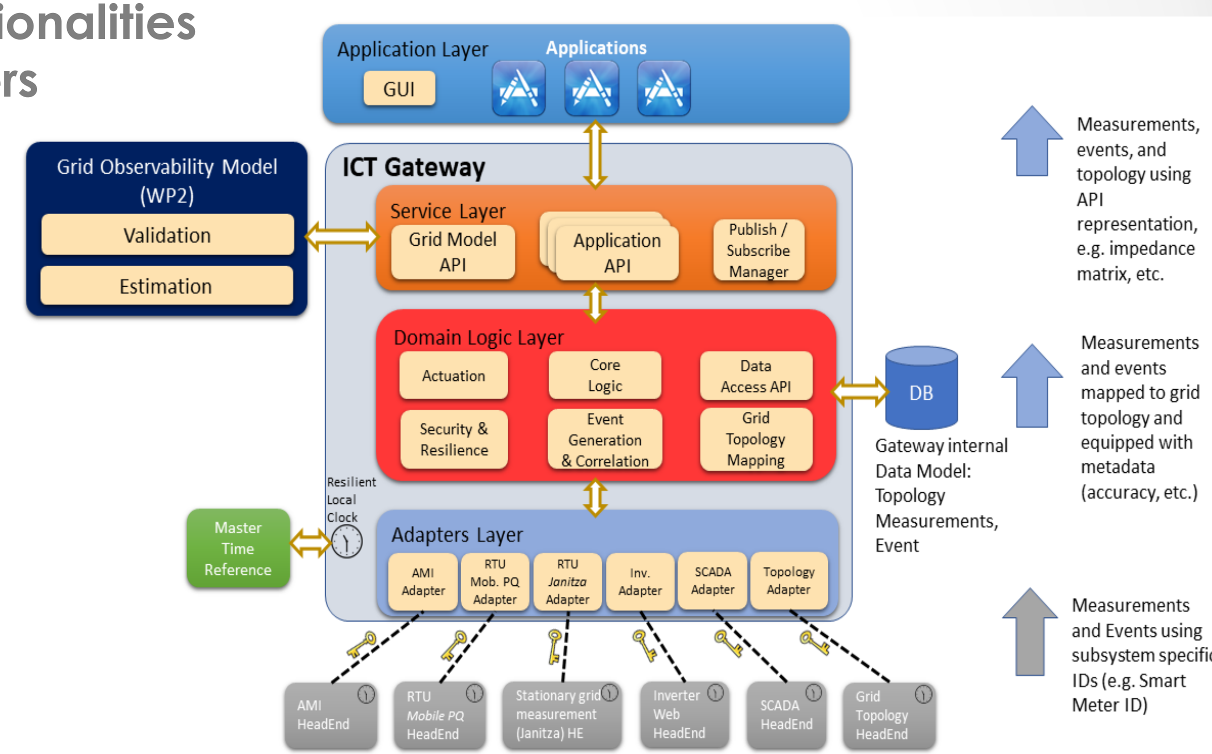
The ICT Gateway Design

- Definition of **ICT Gateway architecture**
- Design of main **functionalities** and relevant **adapters**
- Definition of **APIs**





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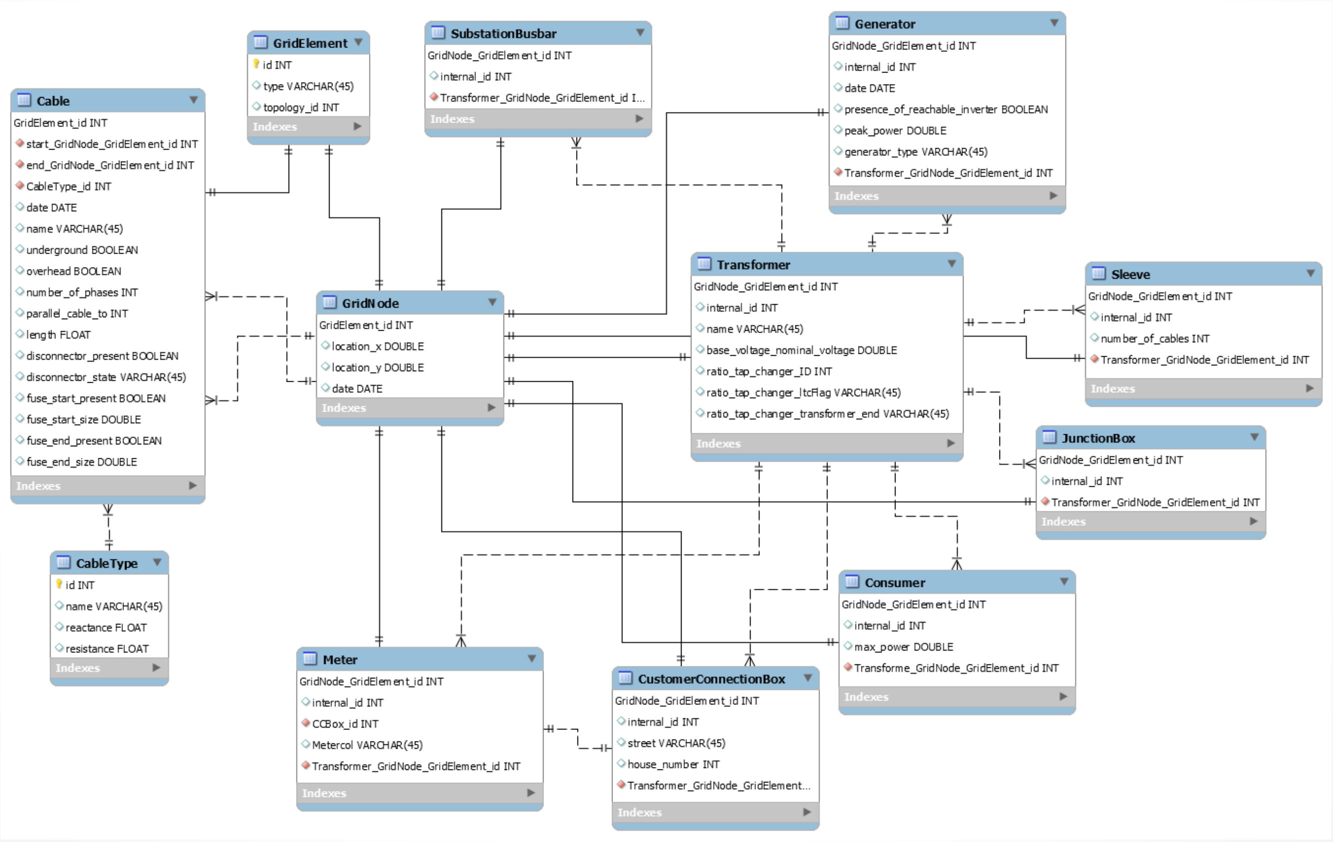
The ICT Gateway Data Model

- Definition of **ICT GW Data Model**



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Threats and hazards analysis

Functional Block Model
- Identification of main block's functions
- Identification of interfaces and data flow

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Threat Analysis
- HAZOP analysis technique
- Analysis through guidewords for functions and interfaces:
  - NOT, OTHER THAN, REPETITION
  - NOT, CORRUPTION, DELAY, MISROUTE, EAVESDROP, SCAN, SPOOF
- Identification of potential deviations from nominal behaviour
- Identification of consequences
- Identification of potential causes

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Risk Assessment
- Probability of occurrence
- Severity of the impact
- Combination of probability and severity

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Countermeasures Identification
- Recommendations for mitigation of the identified threats
- Requirements

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Threats and hazards analysis: results

- The analysis and risk assessment led to identify hazardous events to be addressed to avoid/prevent hazards
- Measurement data for grid observability is a relevant asset to be safeguarded with respect to faults and cyber-attacks
  - Mining this information could lead to instability of the grid, customers' dissatisfaction, loss of money

Source	Destination	Data flow/Information	Guideword	Threat/Hazard Description	Consequence	Cause	Probability (Pre-Mitigation)	Severity (Pre-Mitigation)	Risk Classification (Pre-Mitigation)	Mitigation/Countermeasure	Probability (Post-mitigation)	Severity (Post-mitigation)	Risk Classification (Post-mitigation)
HeadEnd	ICT GW	Measurements from the field	CORRUPTION	Message is corrupted: - the message is not accepted - the message is acceptable but wrong	- ICT GW does not reply to registration. - ICT GW addresses wrong data and event thinking they are correct.	- Environmental condition - Interference - Interruption of data transmission - Cable disconnection - SW bug - HW fault - Malware - Data Injection - Man in the Middle	Highly Probable	Catastrophic	Intolerable	- Authentication techniques - Security Policies - Maintenance procedures - Encryption schema (TLS) - Error and corruption detection mechanisms - Anomaly detection - Intrusion detection	Remote	Catastrophic	Tolerable
HeadEnd	ICT GW	Measurements from the field	DELAY	Message is delayed during transmission	- ICT GW cannot promptly react to events or address fresh data.	- SW bug - Huge amount of Data - Network Congestion - Network Disconnection - Malicious code installed	Highly Probable	Catastrophic	Intolerable	- Timestamping - Authentication - Anomaly detection	Highly Probable	Serious	Tolerable

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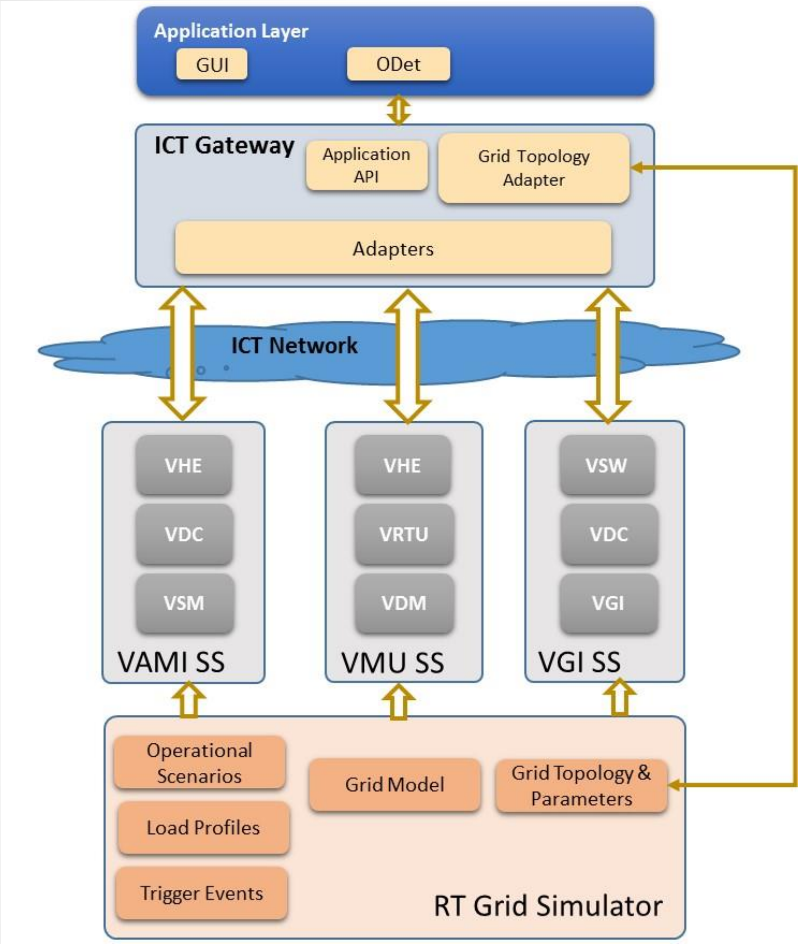
Experimental Evaluation



- assessing core functionalities of developed solutions
- Real-Time HIL approach by using a relevant laboratory environment ->
  - *scalability and applicability of the developed solutions in a wider context*
  - *cover grid conditions that may be difficult to experience during the limited time of the field trails*
- field trials using specific functionalities relevant for the given site test
  - give the confidence to the DSOs regarding the benefits of using the novel applications developed
  - collect data for model validation

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Planned 2020 activities

- Prototype of the first version of ICT GW and Adapters
- Refinement of Data Model
- Integration of components
- Updated of ICT GW functionalities based on
  - lab and field deployments (WP5), further requirements from the application development (WP2)
  - input from DSO after release of the prototype version

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Planned 2020 activities

- Prioritization of threats to identify and design the advanced ICT GW functionalities contributing to security and resilience
- Set up for evaluation of the detection system to be performed based on traces collected from laboratory and field trials
- Definition of countermeasures to counteract identified faults and attacks

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Conclusion

- Net2DG creates software solutions for DSOs,
    - which can be installed quickly and easily
    - and result in cost savings for DSOs.
- Net2DG solutions will reduce grid losses and outages and help with the optimization of grid operation and maintenance
    - using available grid measurement data.
- Net2DG will help regional DSOs become early adopters of digital technology
    - for LV outage diagnosis, grid operation efficiency and voltage quality.
- Net2DG will enable an extended hosting capacity for the integration of renewable energy sources in the low voltage grid
    - by the active use of remotely controllable end-devices in the field.