Improved and Harmonized Smart Grid ICT

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Laboratory integration obstacles

- Electrical power grids are mature infrastructures and have been extensively standardised. There is no standard for what constitutes a smart grid laboratory or what its primary purpose should be. Consequently, the use of ICT systems, the underlying architectures and the availability of interfaces is subject to large variations between facilities.
- Smart grid laboratories are complex infrastructures. They have some unique properties which distinguish them from many other technical installations of comparable complexity.
  - Experimental nature of the installations
  - Changing user groups
  - Evolving configurations
- Finding common ground when simply talking about laboratory integration can already be a challenge

Issues addressed in ERIGrid WP9 (JRA3.1)

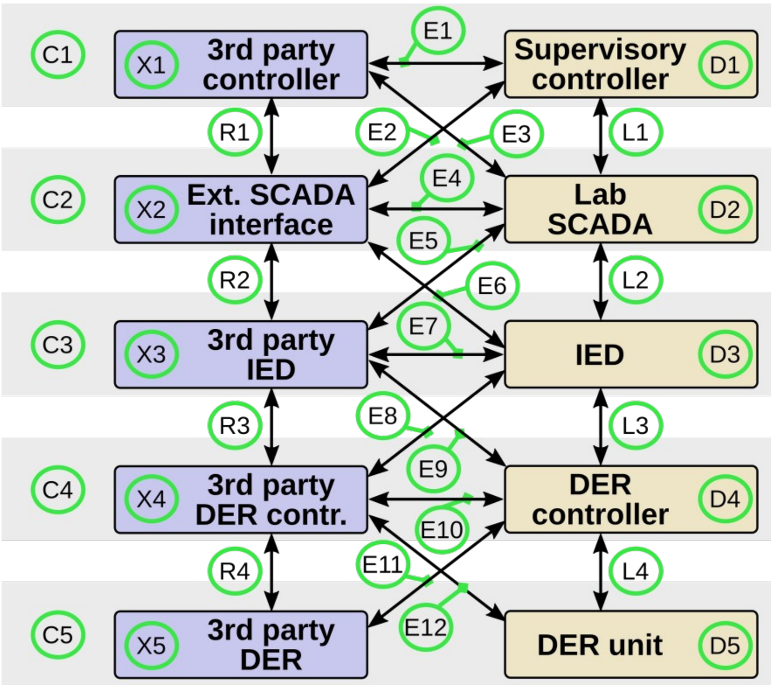
- Generic reference model for control hierarchies, interfaces and data flow in smart grid laboratories
- Documentation of controller deployment procedures
- Uniform naming of signals and objects
- Documentation of complex DER behaviour

The need for a generic reference model

- The availability of communication interfaces between the different parts of a laboratory determines to which degree the laboratory presents itself to the user as a collection of hardware components or as an integrated system
- The automation and control aspects are often missing from descriptions of laboratory capabilities which tend to focus on the performance of the electrical power equipment.
- A one-size-fits-all model is complicated because
  - A wide range of automation levels and concepts is found among partner labs.
  - Ad-hoc automation for individual experiments is not uncommon.
  - Automation may involve communication between lab components and/or between the lab and third party equipment (under test)
  - The automation may be considered as infrastructure, as part of the system under investigation, or a combination of both

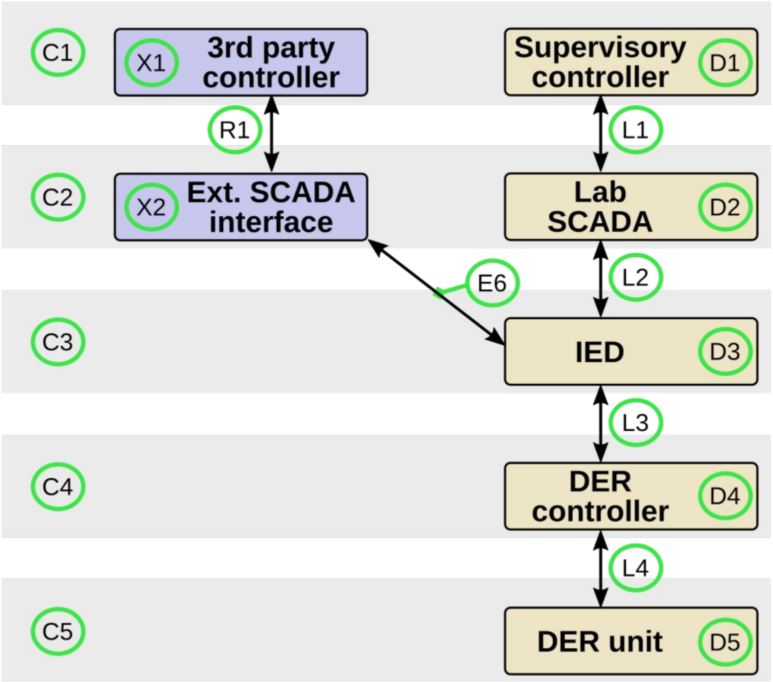
Generic reference model: Description

- The model abstracts away from individual devices, controllers, protocols etc. as well as time, in order to focus on classes of controllers and interfaces.
- Definition of five hierarchy levels at which control functionality may be deployed – both internal to the lab and external.
- Definitions of 20 communication interface locations
- Use cases for 12 interfaces between lab installations and external systems
- Partner examples of concrete experiment configurations



Generic reference model: Example (AIT SmarTEST)

- A third-party system-level controller (e.g. power balancing control) is directly interacting with DER components in the laboratory through a gateway/IED.
- The laboratory internal SCADA system is used for the configuration of the experiment, but not during the execution phase.



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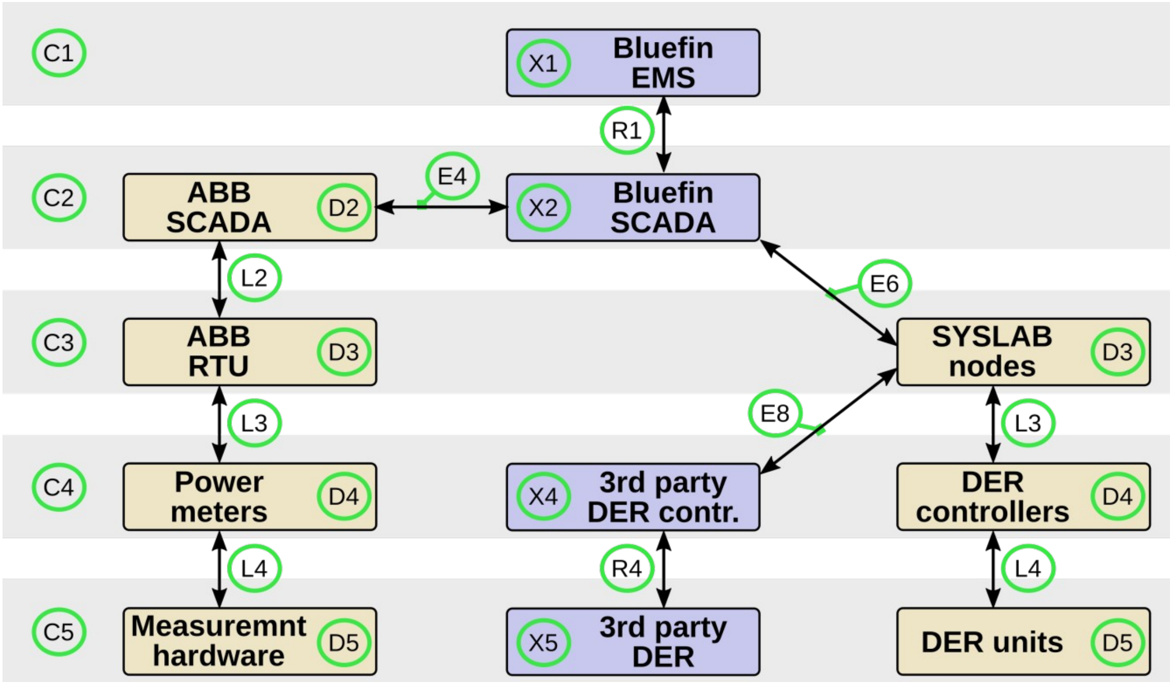
Generic reference model: Example (DTU SYSLAB & Electric lab)

- Performance evaluation of a third-party smart grid automation system
- Augmentation of a low automation host laboratory (DTU Electric lab) with components and control infrastructure from a highly automated laboratory (DTU SYSLAB)



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Controller deployment procedures

- Deploying controllers – software or hardware, from the unit level to the system level - is important for many types of smart grid testing.
- It is very difficult for an outside user or research partner to gain an overview of the exact capabilities of a laboratory with respect to controller deployment. This complicates the selection of a suitable facility for an experiment.
  - Uniqueness of the individual laboratories
  - Many possible interaction patterns
  - Policies and safety/stability concerns (an interface exists, but it should not be used)
- Survey of controller hosting capabilities across partner labs:
  - Physical capabilities (e.g. centralized vs. distributed)
  - Interfaces (e.g. standardisation, authentication)
  - Procedures (e.g. manual vs. semiautomatic)

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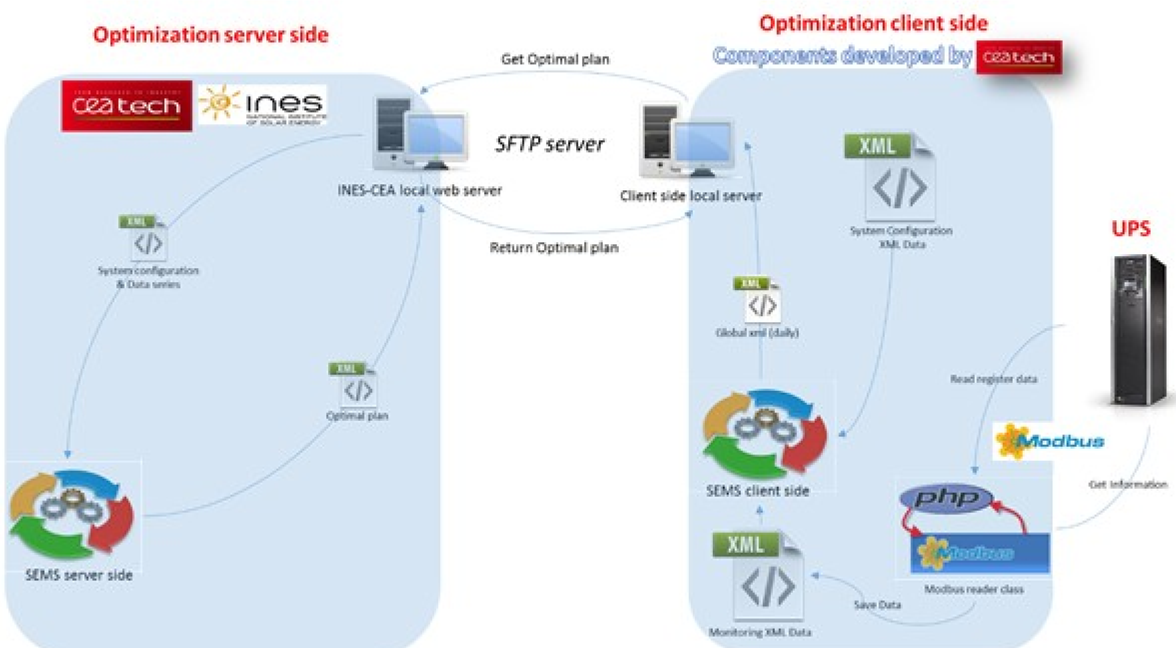
Controller deployment example

Example from CEA: Distributed optimizing controller, consisting of a client part deployed directly in the laboratory and a server part at a remote site

- Client deployment acts as / replaces a local IED (D3 in the reference model)
- Server part is a remote supervisory controller (X1), communicating to the client through an "external" (ad-hoc) interface (X2)



Signal and object naming

- The partner labs have been developed from very different architectural viewpoints, resulting in different ways of modelling information.
- Establishing a harmonized object and signal naming convention is necessary for machine-to-machine communication between labs.
- Existing standards lack flexibility:
  - Lab-specific description of primary hierarchy (physical, electrical, automation based, information based,…)
  - Additional domains (control, communication, heat, gas,…)
  - Unambiguous description of components which belong to multiple hierarchies and/or multiple domains
- ERIGrid has developed naming conventions suitable for the detailed description of static (objects) and dynamic (signals) data in smart grid laboratories.

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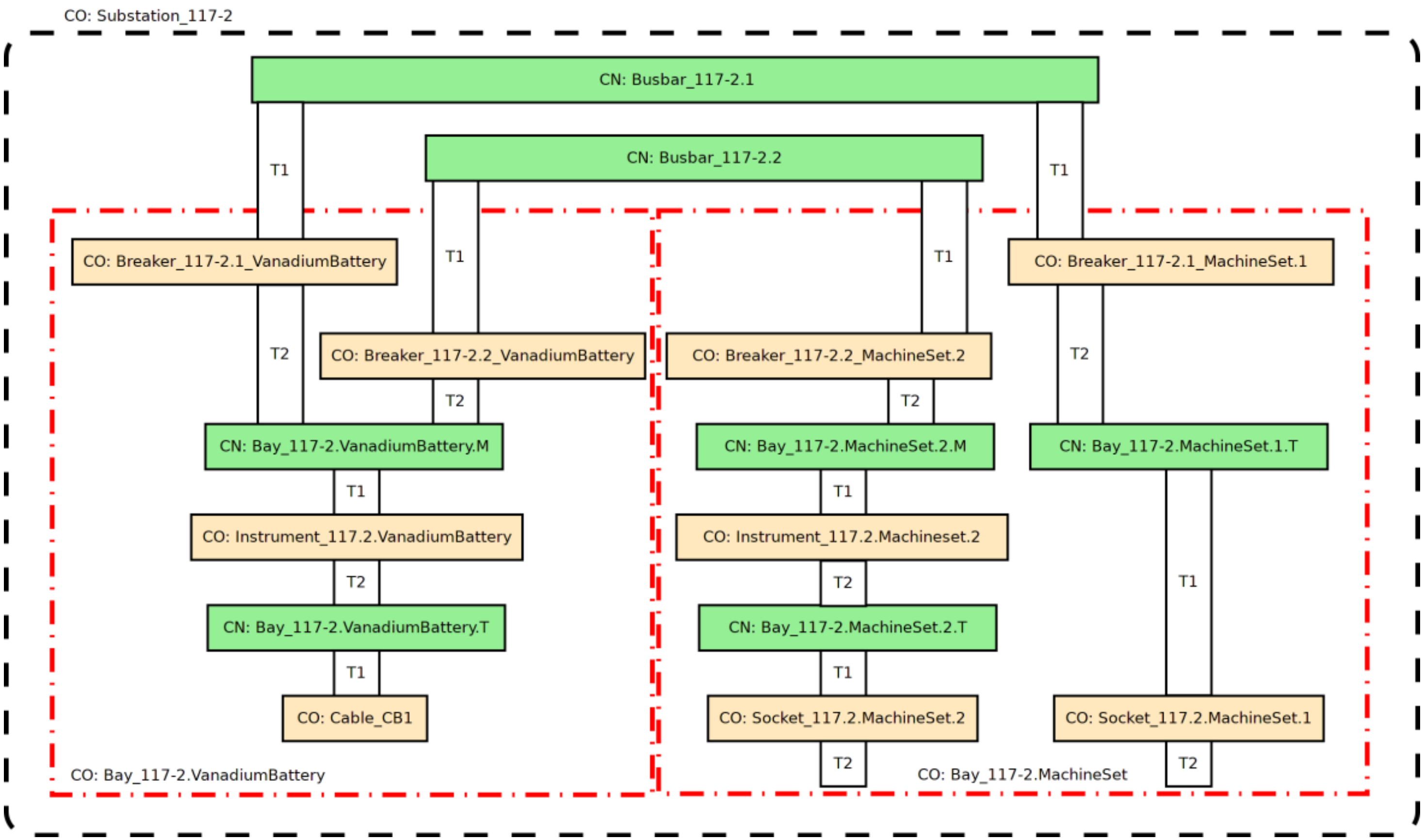
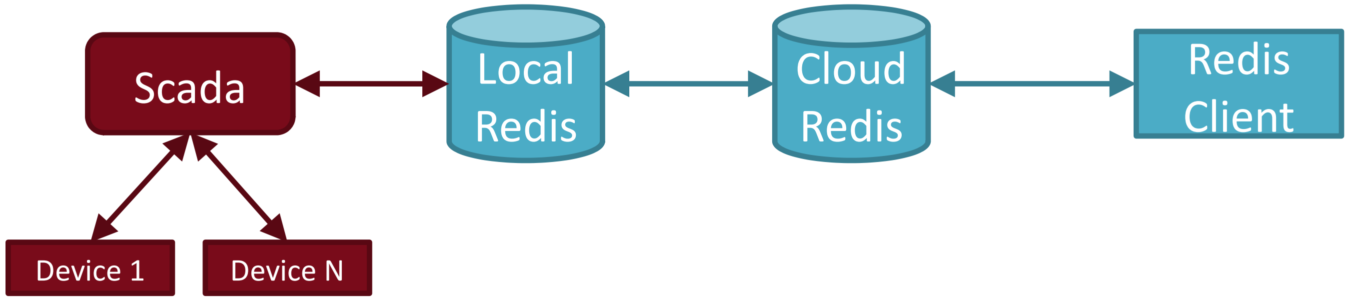
Signal and object naming: Lab database

- Object naming application: NA5.3 laboratory database



Signal and object naming: JaNDER

- Signal naming application: JaNDER virtual research infrastructure



IO List for Erigrid RIs

File Edit View Insert Format Data Tools Add-ons Help Last edit was made on October 1 by anonymous

fx LIST OF REDIS VARIABLES

	A	B	C
1	LIST OF REDIS VARIABLES		
2	RI namespace: **DTU** - Device: **Gaia wind turbine**		
3	Tag	Description	Comments
4	DTU::Generator_Gaia:M_EA_Watt.instMag	AC active power at turbine PCC [W]	NaN=value unknown or out of date. (+)=generati window average to the power output value. For f substation instrument (DTU::Instrument_715-2.G
5	DTU::Generator_Gaia:M_EA_Volt.instMag	AC line-line voltage at turbine PCC (three phase average) [V]	NaN=value unknown or out of date
6	DTU::Generator_Gaia:M_ME_RotSpd.instMag	Rotor RPM [min-1]	NaN=value unknown or out of date
7	DTU::Generator_Gaia:M_ME_GenSpd.instMag	Generator RPM [min-1]	NaN=value unknown or out of date
8	DTU::Generator_Gaia:M_ME_WdSpd.instMag	Nacelle wind speed [ms-1]	NaN=value unknown or out of date
9	DTU::Generator_Gaia:I_CT_TurSt.stVal	Turbine operating state [ENUM: -1=unknown, 0=stopped, 1=standby, 2=starting, 3=motorstart, 4=running, 5=freewheel, 6=stopping]	
10	DTU::Generator_Gaia:A_CT_EmStAlm.actSt	Emergency stop alarm state [ENUM: -1=unknown, 0=clear, 1=active]	
11	DTU::Generator_Gaia:C_CT_SetTurOp.cmVal	Turbine operation command [ENUM: 0=no command, 1=stop turbine, 2=start turbine]	Value of the db key is always reset to 0 (=neutral
12	DTU::Generator_Gaia:C_CT_EmStAlm.ack	Reset emergency stop command [ENUM: 0=no command, 1=reset]	Value of the db key is always reset to 0 (=neutral
13	DTU::Generator_Gaia:I_CO_AccPerm.stVal	Available access permissions [ENUM: 0=none, 1=read, 2=read+write]	Indicates whether the wind turbine IED allows ac
14	DTU::Generator_Gaia:I_CO_IEDOnline.stVal	Turbine IED online status [ENUM: 0=offline, 1=online]	Indicates whether the wind turbine SYSLAB node
15	DTU::Generator_Gaia:I_CO_DEROnline.stVal	Turbine DER controller online status [ENUM: 0=offline, 1=online]	Indicates whether the wind turbine node can con
16	DTU::Breaker_715-2.1_Gaia:I_EA_Pos	Breaker position [ENUM: -1=unknown, 0=open, 1=closed]	connecting wind turbine to busbar 1, substation
17	DTU::Breaker_715-2.2_Gaia:I_EA_Pos	Breaker position [ENUM: -1=unknown, 0=open, 1=closed]	connecting wind turbine to busbar 2, substation
18	DTU::Instrument_715-2.Gaia:M_EA_Watt.instMag	AC active power at grid connection point [W]	NaN=value unknown or out of date. (+)=flow into
19	DTU::Instrument_715-2.Gaia:M_EA_Var.instMag	AC reactive power at grid connection point [VAr]	NaN=value unknown or out of date. (+)=flow into
20	DTU::Substation_715-2:I_CO_AccPerm.stVal	Available access permissions [ENUM: 0=none, 1=read, 2=read+write]	Indicates whether the substation IED allows acce
21	DTU::Substation_715-2:I_CO_IEDOnline.stVal	Substation IED online status [ENUM: 0=offline, 1=online]	Indicates whether the substation SYSLAB node i
22	DTU::Substation_715-2:I_CO_DEROnline.stVal	Substation controller online status [ENUM: 0=offline, 1=online]	Indicates whether the substation node can comm

Complex DER component behaviour

- Laboratory equipment, in particular DER units with embedded controllers, often exhibits complex and undocumented behaviour when operated during experiments. Available documentation often focuses on the operation under standard conditions.
- Examples include deratings, internal limits, safety circuits, alternate operating modes, functions added as part of laboratory integration etc.
- The productive use of a particular component often relies on unofficial knowledge associated with experienced laboratory staff – sometimes a single person.
- ERIGrid conducted a survey of examples across partner labs. The results can be seen as a first step towards a more systematic documentation.

Complex DER behaviour example

Example: Lead-acid battery system (ICCS/NTUA)

- External limiting of the charging/discharging current introduced as a workaround due to inverter instability in certain SOC ranges
- Current limiting (Setpoint capping) by the DC/AC inverter and the DC/DC converter
- Droop controller (locally developed, not in factory documentation) added to the battery system at the IED level
- Additional operating modes (locally developed, not in factory documentation): Grid forming, single phase operation, DC-only operation