

ICT standards for smart grids: IEC 61850, CIM and their implementation in the ERIGrid project

March 23, 2018

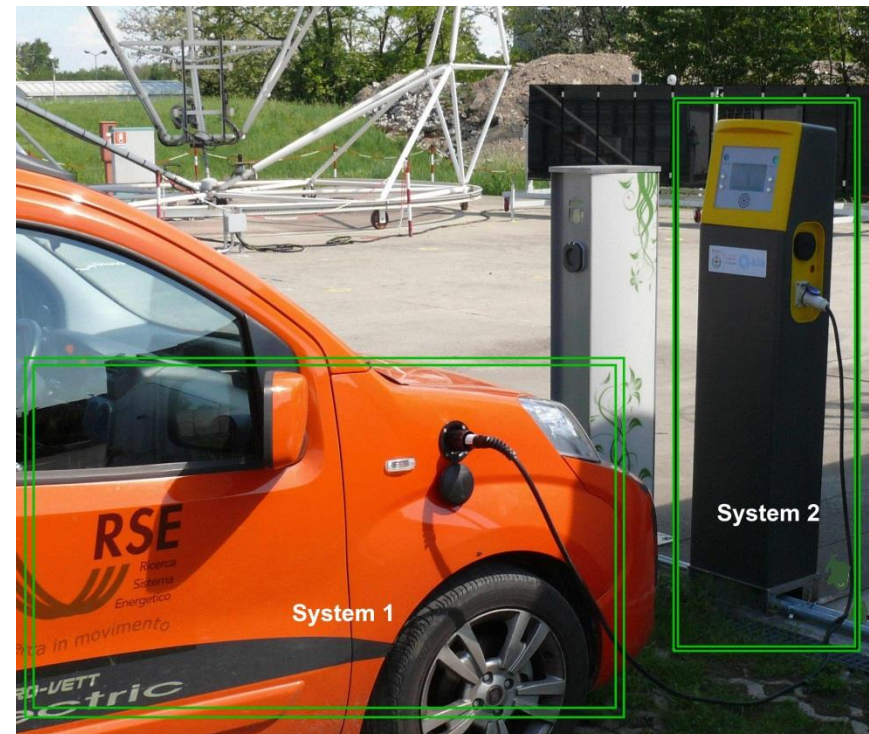
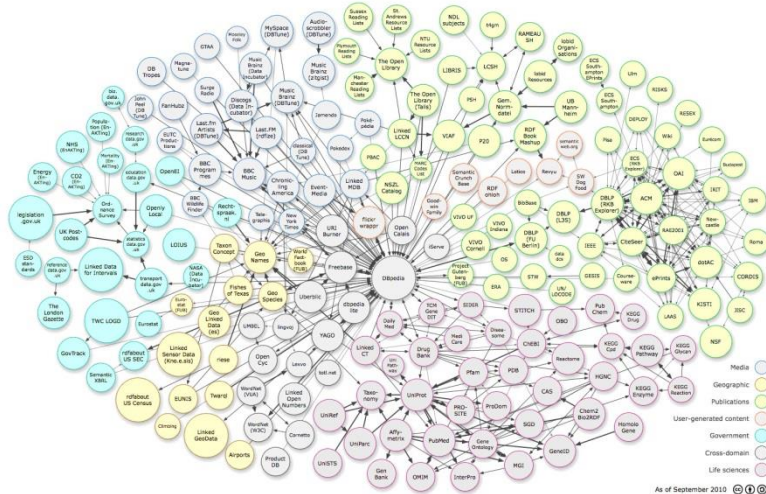
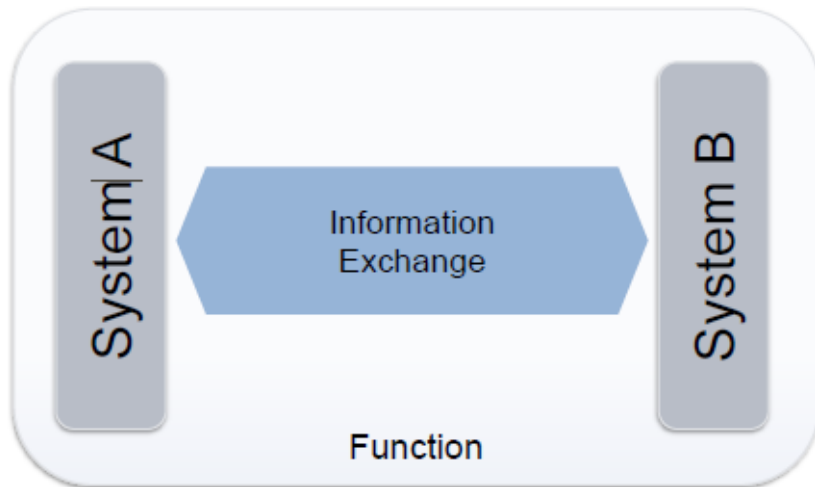
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Agenda

- ICT Interoperability in Smart Grids
- IEC 61850 - General concepts
- ERIGrid context and software platform (JaNDER)
- IEC Common Information Model – General concepts
- IEC Common Information Model – JaNDER extensions for CIM

What is «interoperability» ?

It is the ability that systems have to exchange informations and use them in order to perform required functions

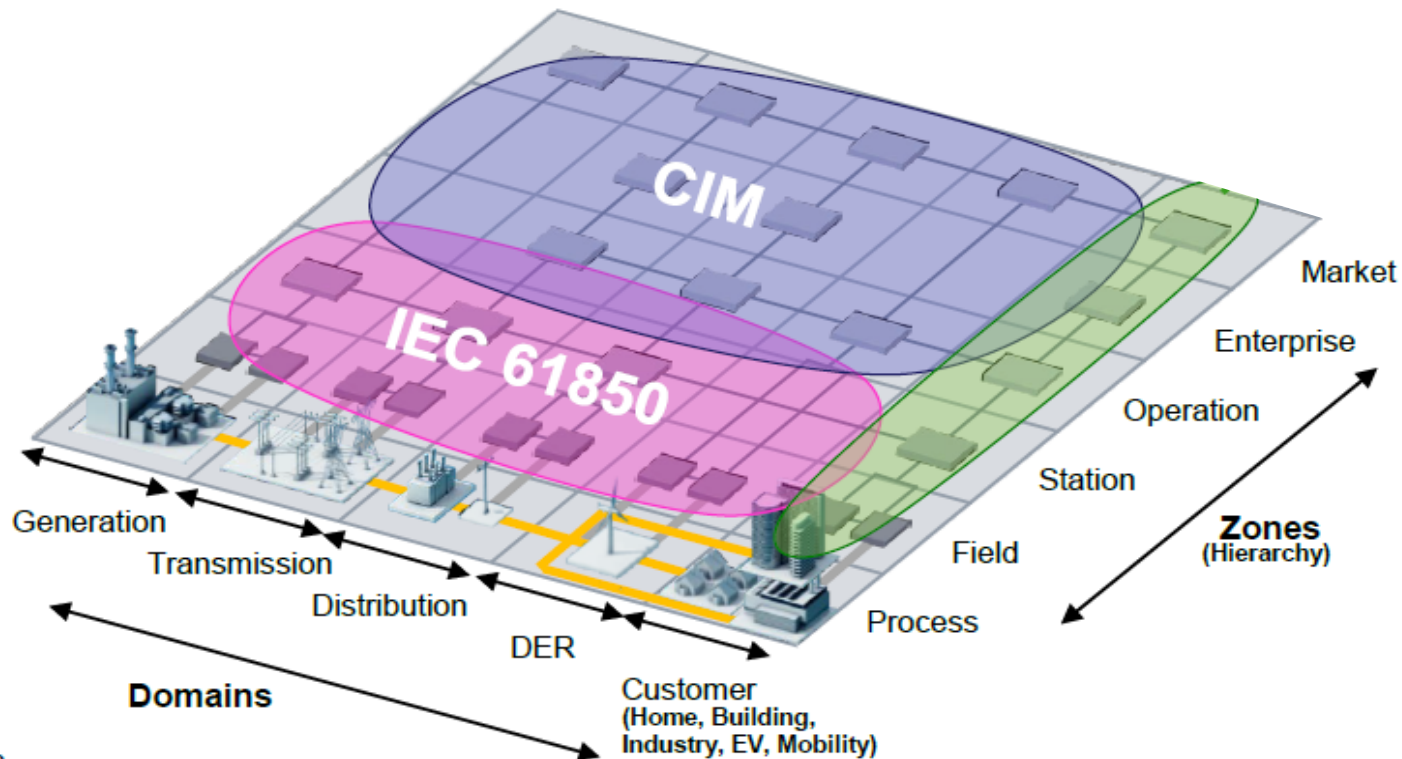


The integration of systems

- The realisation of complex systems like «Smart Cities» and «Smart Grids», requires the integration of a lot of systems
- The integration of systems needs the adoption of standard solutions that can guarantee interoperability
- In front of a complex context like this, it's not enough to manage big data and/or specify new communication protocols
- A global approach is needed, by increasing the value of “data” through a description of their meaning
- In this way simple data become "information" that means «knowledge» of a context/domain

- The IEC 61850 and CIM standards have been developed in the electrical energy sector to enable the integration of complex systems like Smart Grids
- Their main focus is about formally defining the knowledge associated to the electrical domain, by using **data models**.
- The sharing of a common data model provides a basis for understanding information exchanged between systems, enabling in this way their smart use.
- At lower level, they also specify communication protocols and services for exchanging information defined in the data model.

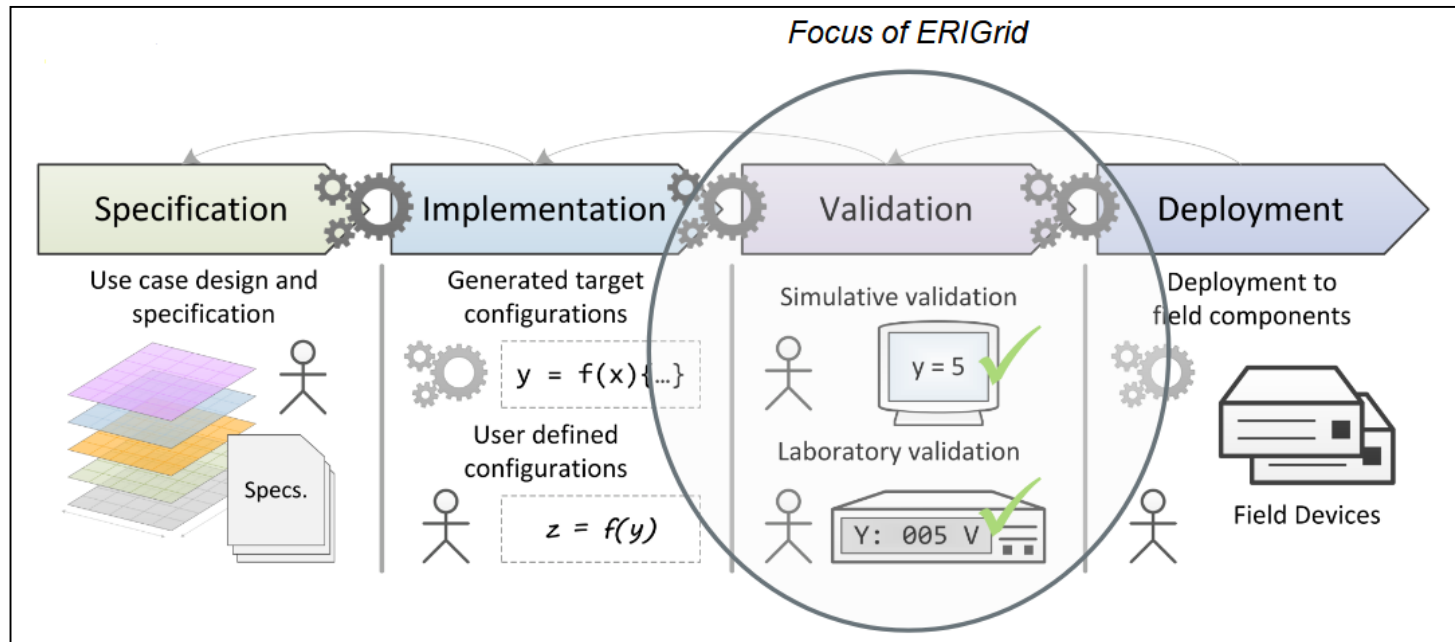
The main ICT standards for smart grids



ERIGrid – quick overview

Intelligent power networks are urgently required to integrate the growing number of distributed energy sources into our energy system.

Developing an integrated research infrastructure for smart grid systems is the target of the EU-funded ERIGrid - European Research Infrastructure supporting Smart Grid Systems Technology Development, Validation and Roll Out - project.



IEC 61850

IEC 61850 - Introduction

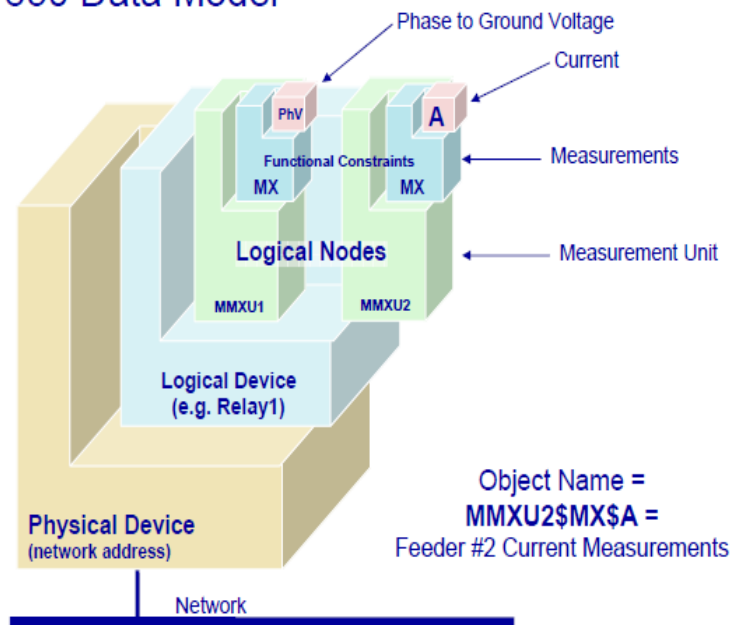
IEC 61850 is a standard produced by the IEC (International Electrotechnical Commission) with the original purpose of:

- describing the devices inside a substation from a functional point of view;
- allowing the exchange and use of this describing information both in design/configuration (through the use of dedicated XML files) and during runtime (through proper communication protocols).

The widespread use of the standard in substation automation has led to various proposals for extending its use in many Smart Grid domains.

IEC 61850 – data model

IEC 61850 Data Model



It defines standard data structures and naming for describing a device, organized in a **data model**.

For example, breaker position is always called «XCBR.Pos» by **every vendor**.

Device configuration is based on standard XML files, which can eventually describe the whole system (**SCD file – Substation Configuration Description**).

Origins: substation automation

A substation automation project starts from the definition of the single line diagram (SLD), defining the power equipment and topology of the substation.

SCL (Substation Configuration Language), defined by IEC 61850, allow the representation of an SLD in XML. Engineering tools generate this file automatically from the SLD drawing.

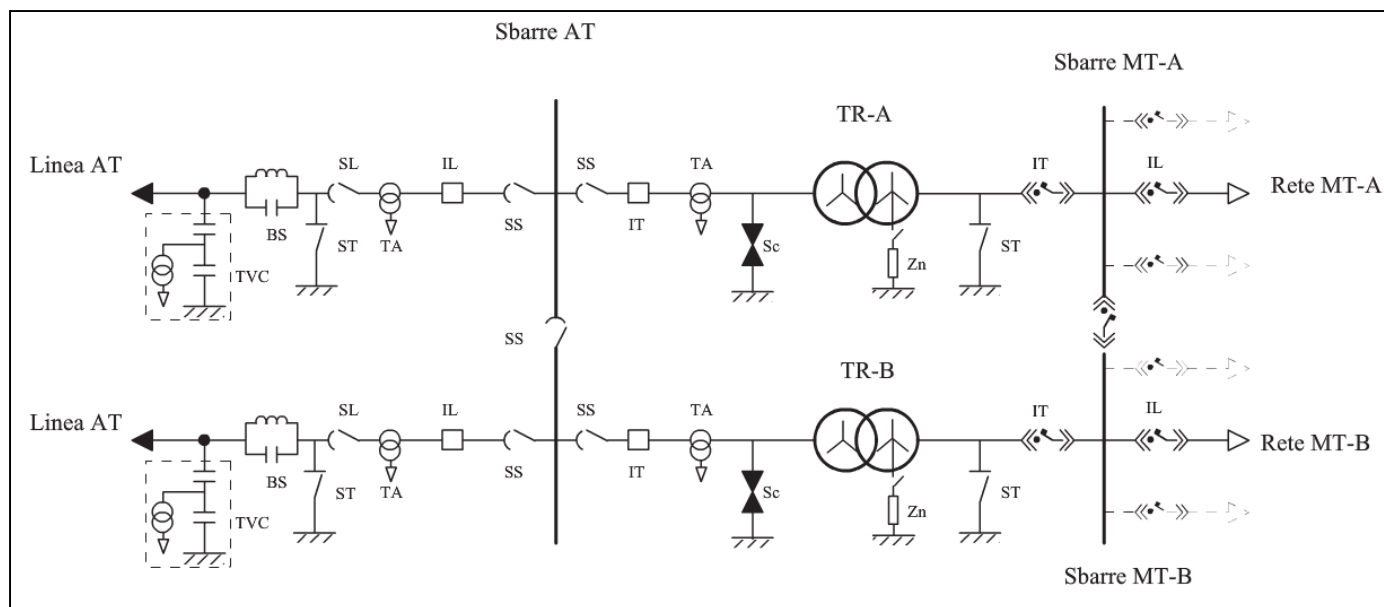


Image source: F. M. Gatta, Impianti Elettrici vol.1, 2014

Adding automation functions

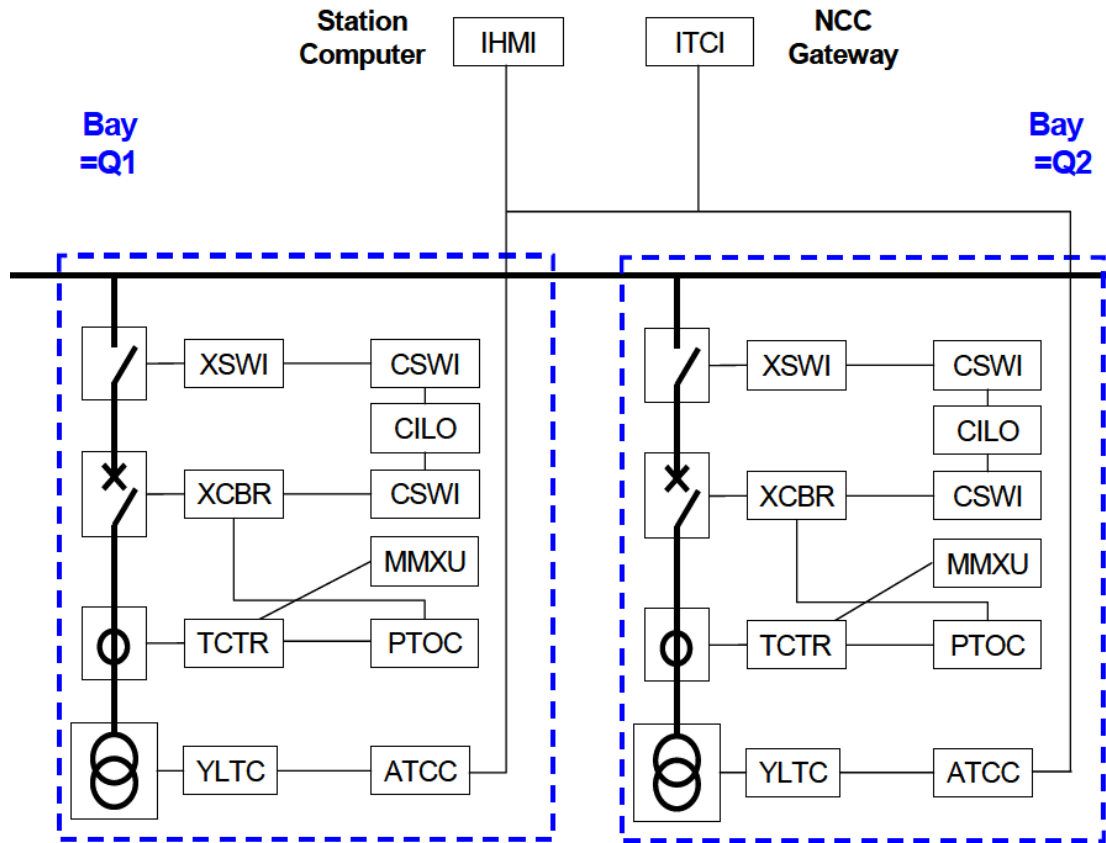


Image source: Cigre SC B5

Power equipment can then be associated with measurements and automation functions. The resulting XML file is called SSD (System Specification Description).

The functions have standard name and attributes, whose semantics are defined in so-called **Logical Nodes**.

Mapping functions on real devices

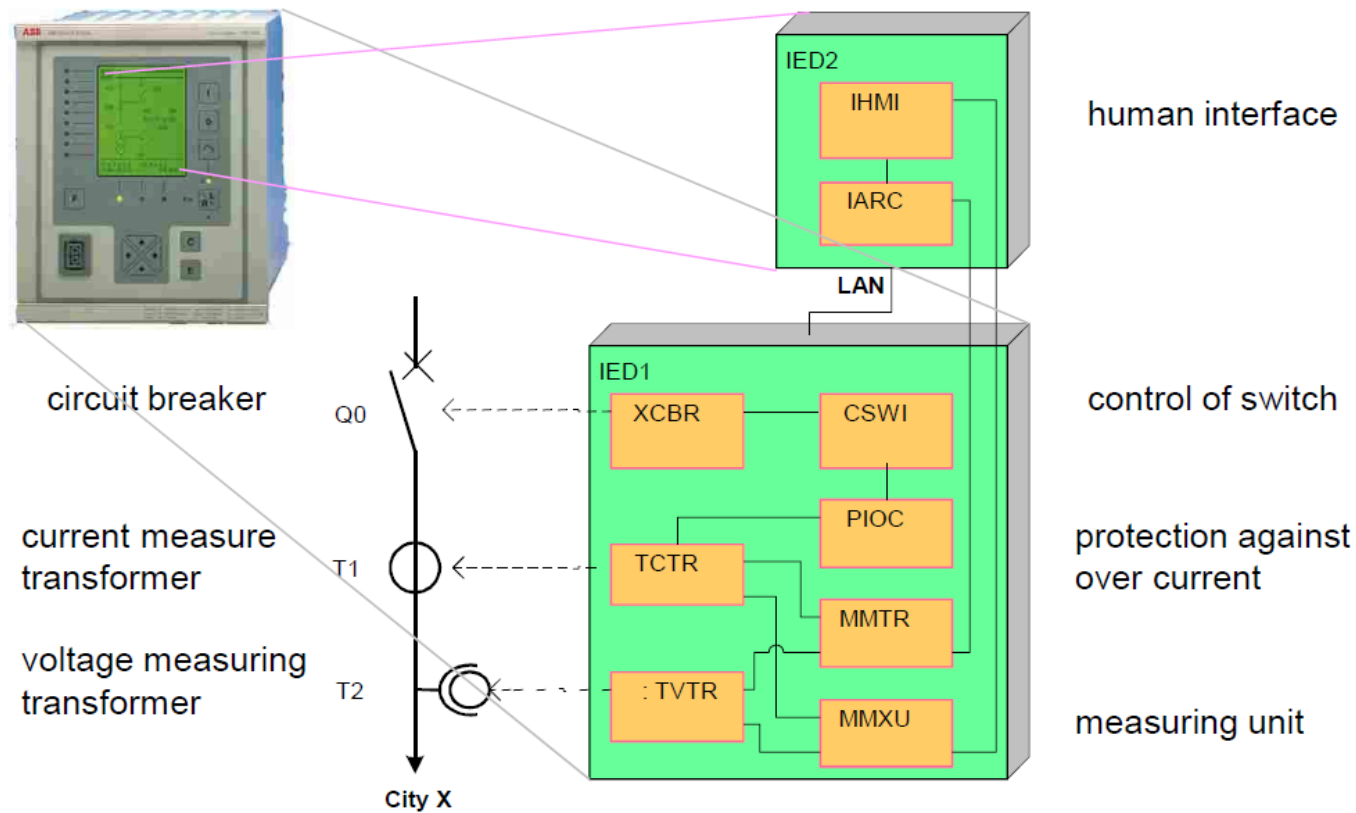


Image source: ABB

The defined functions (logical nodes) can then be mapped on physical devices (IED, Intelligent Electronic Device).

The whole process

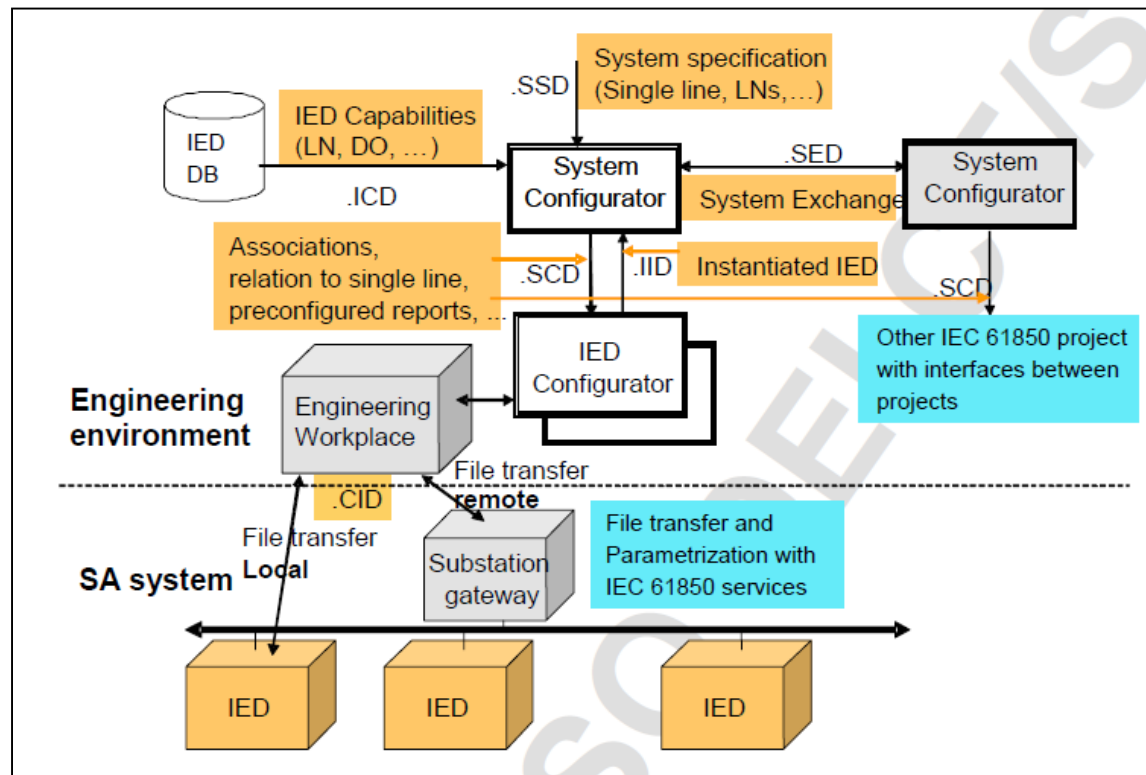
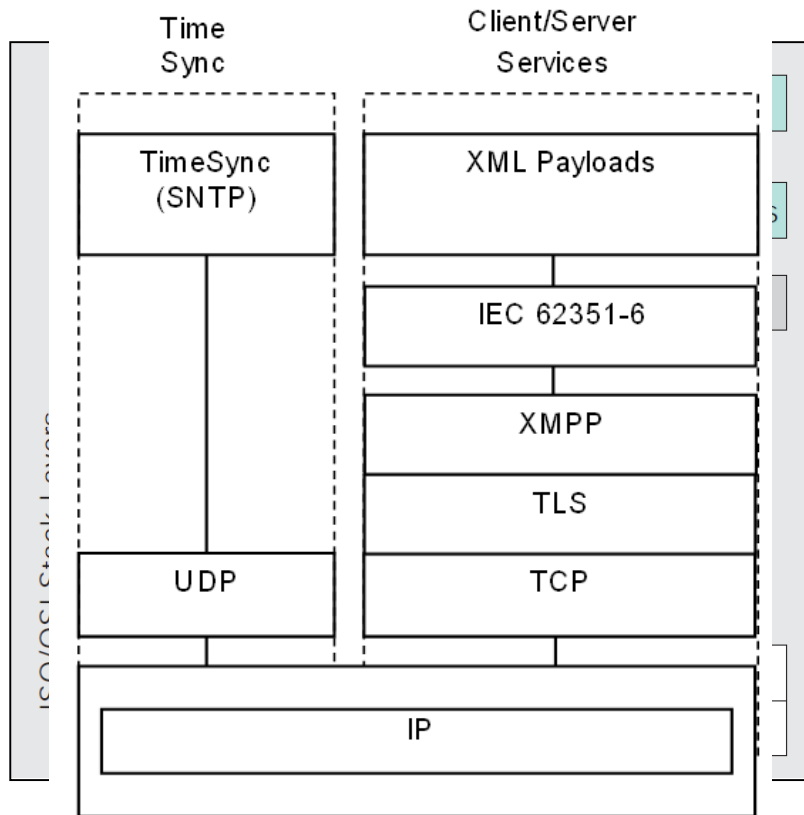


Image source: IEC 61850-6

Each vendor provides an XML file describing its IEDs (**ICD, IED Capability Description**). Combination of the SSD and ICDs produces the full automation project (**SCD, Substation Configuration Description**), from which one can extract configuration files for each IED (**CID, Configured IED Description**).

Communication services



peer-to-peer

- Fast events (GOOSE protocol).
- Measurements (SV protocol).

client-server

- MMS protocol (Manufacturing Message Specification).
- XMPP protocol (not yet published)

IEC 61850 also supports time synchronization mechanisms via SNTP or IEEE 1588 (Precision Time Protocol).

Process bus and station bus

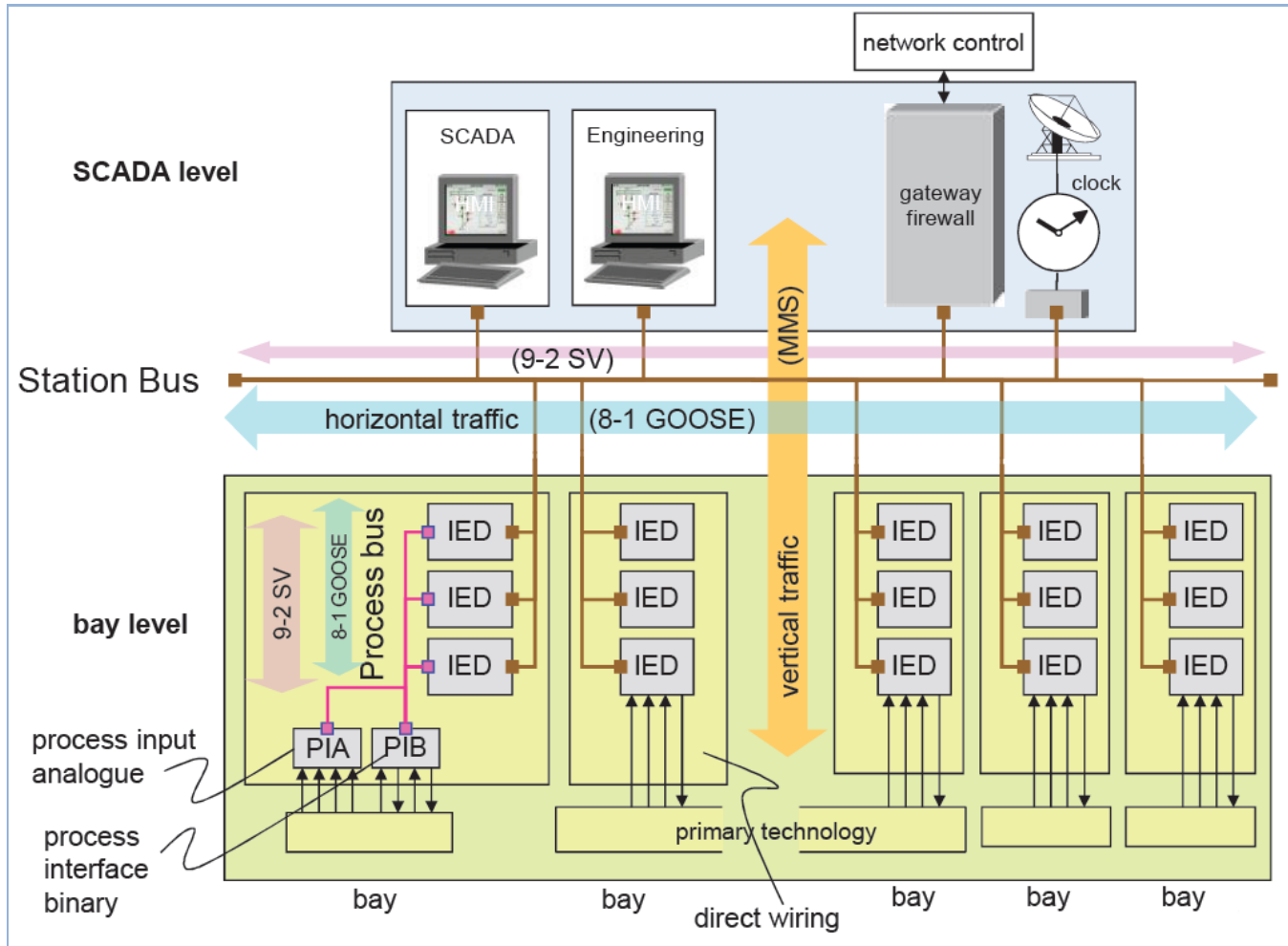


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Going outside the substation

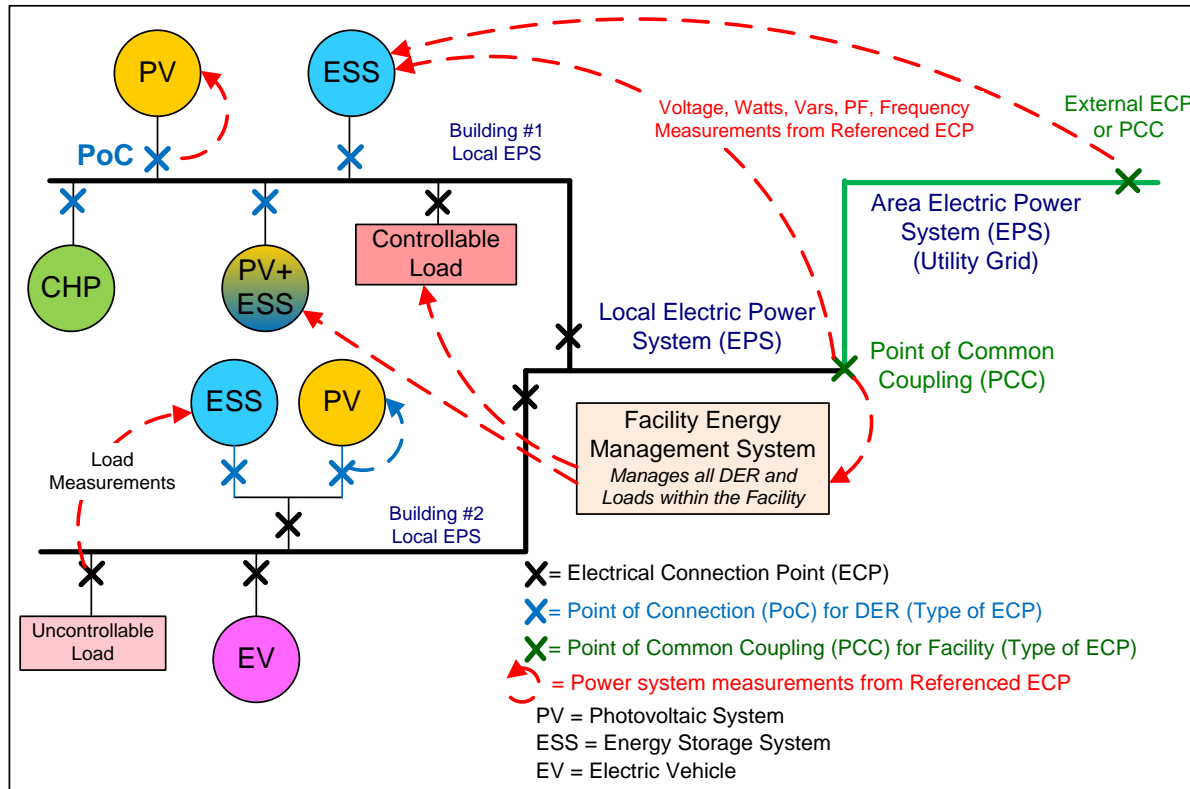


Image source: IEC 61850-7-420

The perspective is to define new logical nodes and use the XMPP protocol instead of MMS.

This is very important for ERIGrid, **but not available yet:**

- XMPP mapping not published
- DER and DA standards still under development
- Mapping of network codes also under development

IEC 61850 – pros and cons

From ERIGrid perspective

Main advantages of IEC 61850:

- Standard semantics
- Very detailed engineering process (for Substation Automation)
- Globally accepted standard (for Substation Automation)

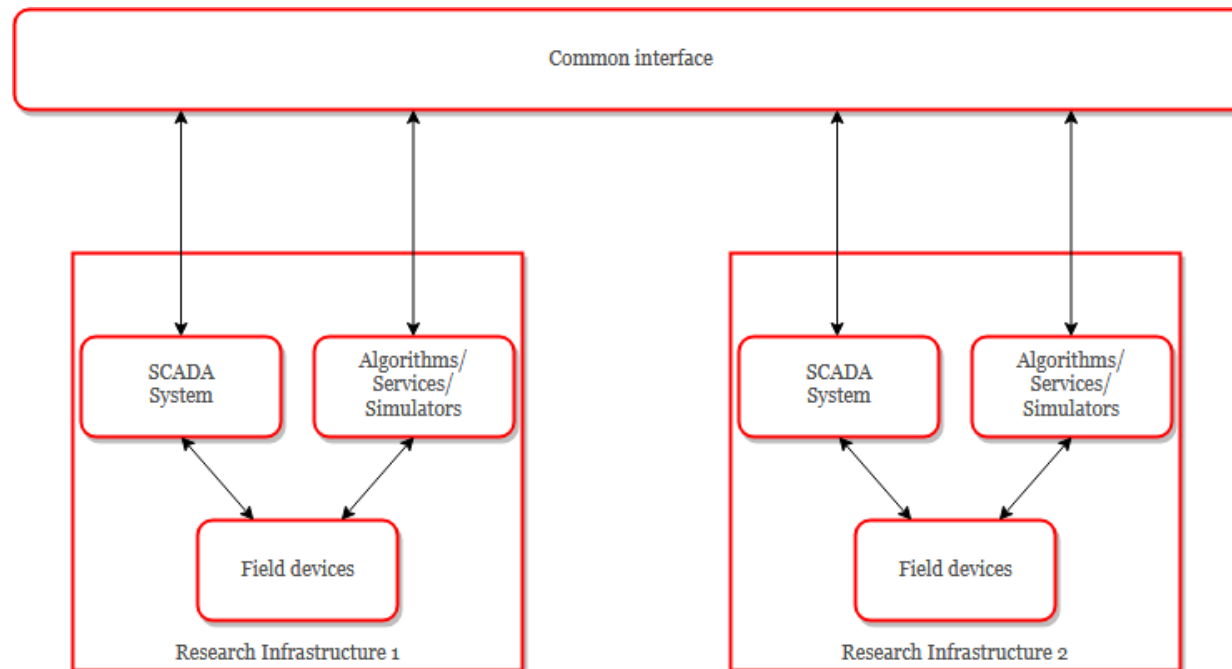
Main disadvantages of IEC 61850:

- Complex
- DER and Distribution Automation extensions still under development
- XMPP mapping still under development (therefore, usage over Internet still problematic at the moment)
- Getting access to the standard can be difficult

ERIGrid context

One of the research activities of the ERIGrid project deals with the remote interconnection of research infrastructures for the purpose of performing online joint distributed tests and build a Virtual Research Infrastructure (VRI).

Idea: first build a “virtual station bus” connecting all facilities, then apply IEC 61850 over it. (...and **open source** the solution)



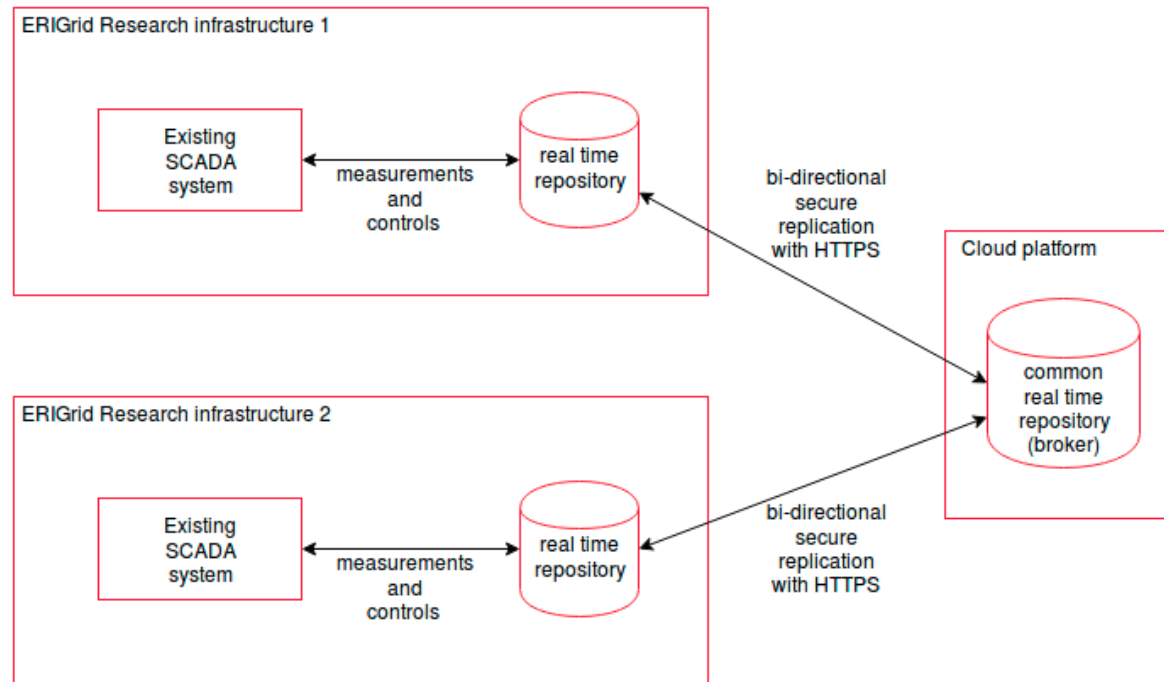
ERIGrid JaNDER platform (1)

The remote connection platform is called JaNDER (Joint Test Facility for Smart Energy Networks with Distributed Energy Resources). It is structured with three levels:

- Level 0: virtual bus for remote interconnection of facilities
- Level 1: IEC 61850 interface on top of Level 0
- Level 2: CIM SCADA interface on top of Level 0

ERIGrid JaNDER platform (2)

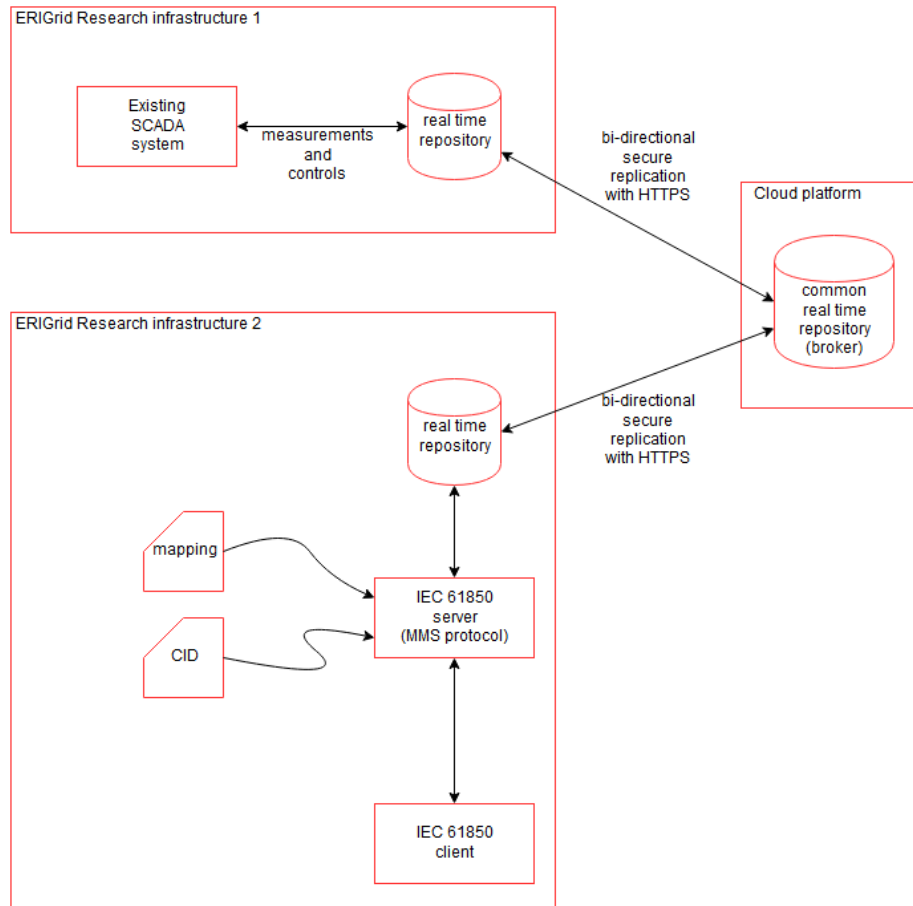
- Level 0: virtual bus for remote interconnection of facilities



All components are open source. In particular the replication software was developed directly by ERIGrid and can be downloaded here:
<https://goo.gl/jfPKQs>

ERIGrid JaNDER platform (3)

- Level 1: IEC 61850 interface



The IEC 61850 server software is based on the OpenIEC61850 library developed by Fraunhofer ISE, with Redis interfacing developed by ERIGrid (can be downloaded here: <https://goo.gl/cK3t1W>)

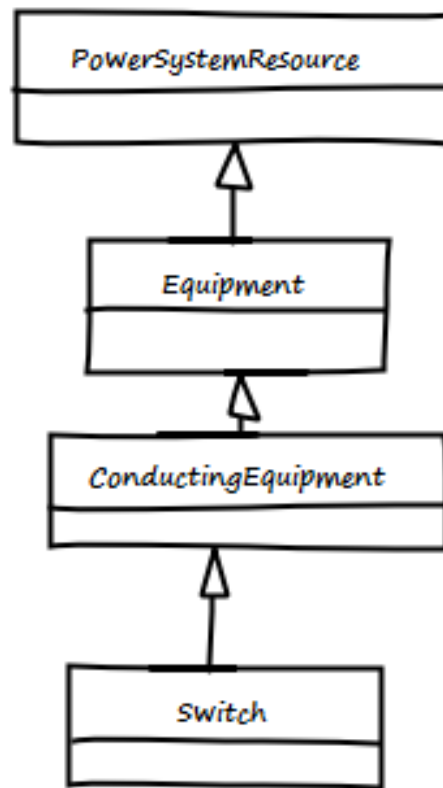
IEC «Common Information Model» (CIM)



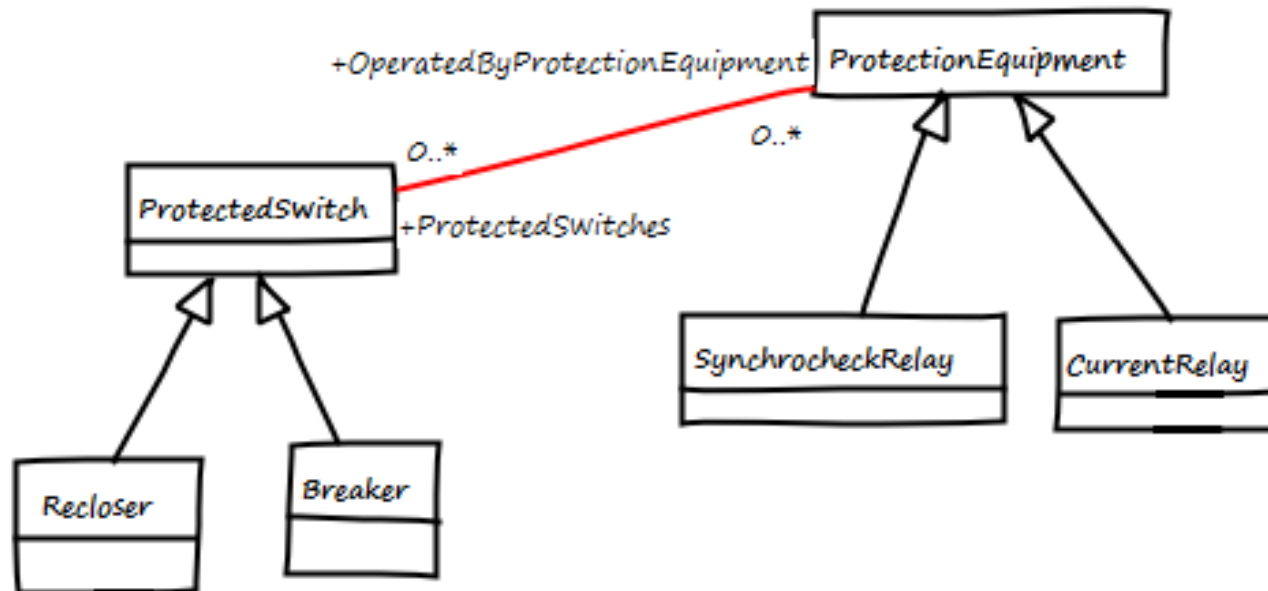
IEC “Common Information Model”

- The “Common Information Model” («**CIM**») is a Data Model expressed by a UML Class diagram
- CIM represents the main resources and the relationship between them, for the management of the electric system
- Expressing the knowledge associated to the electrical domain, CIM represent its base ontology

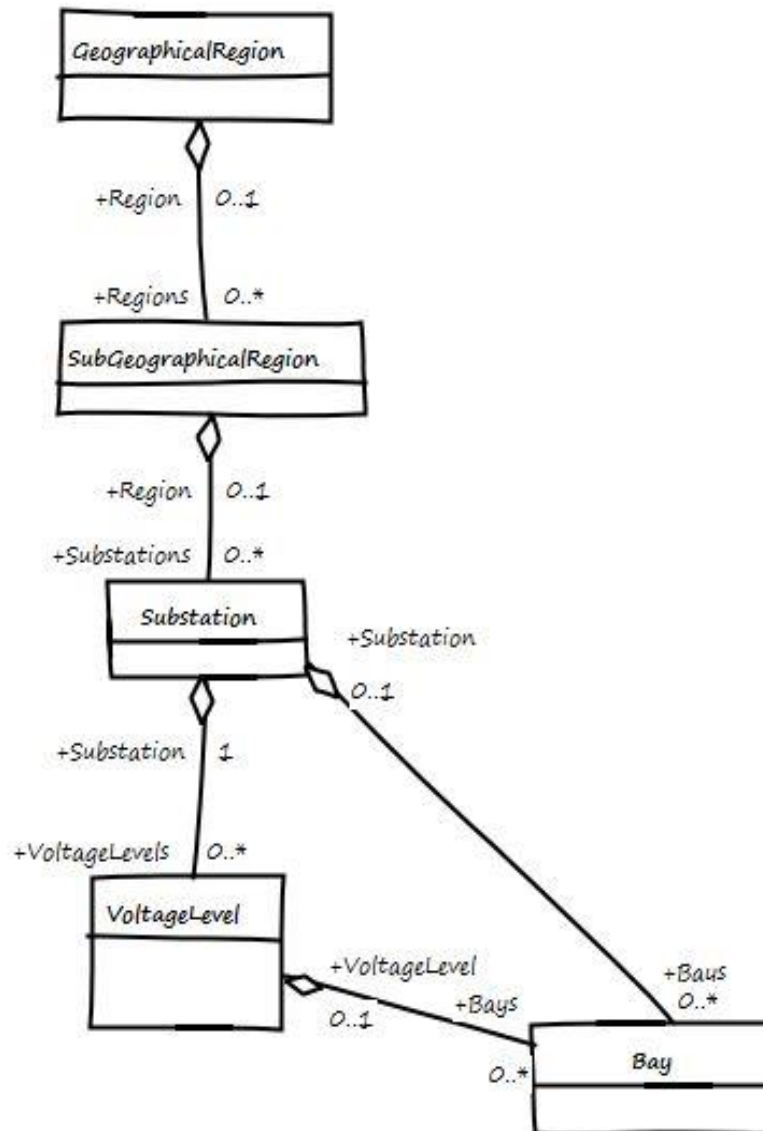
Example of classes inheritance in «CIM»



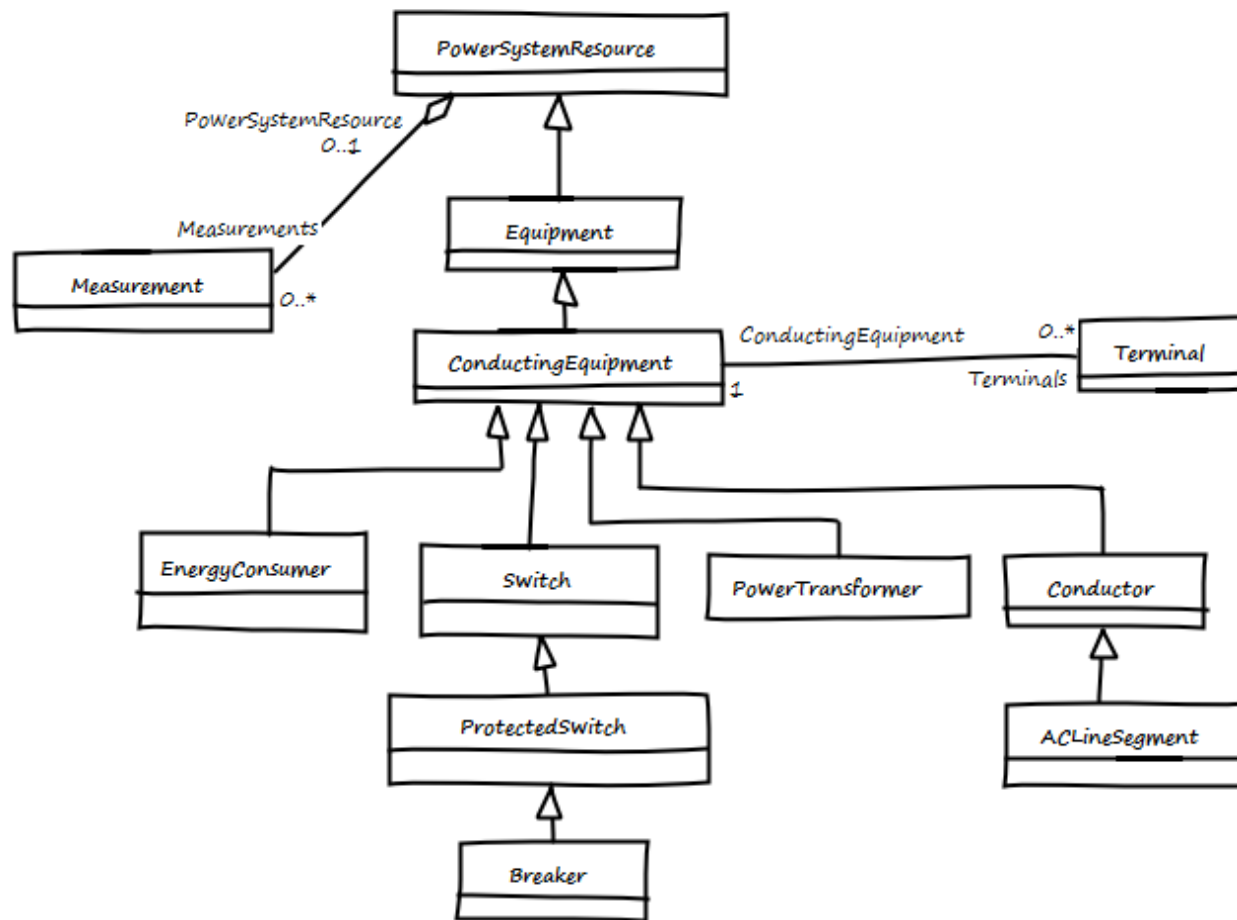
Example of association in «CIM»



Example of aggregation in «CIM»



«CIM» expresses the electric domain knowledge



CIM – Main application contexts

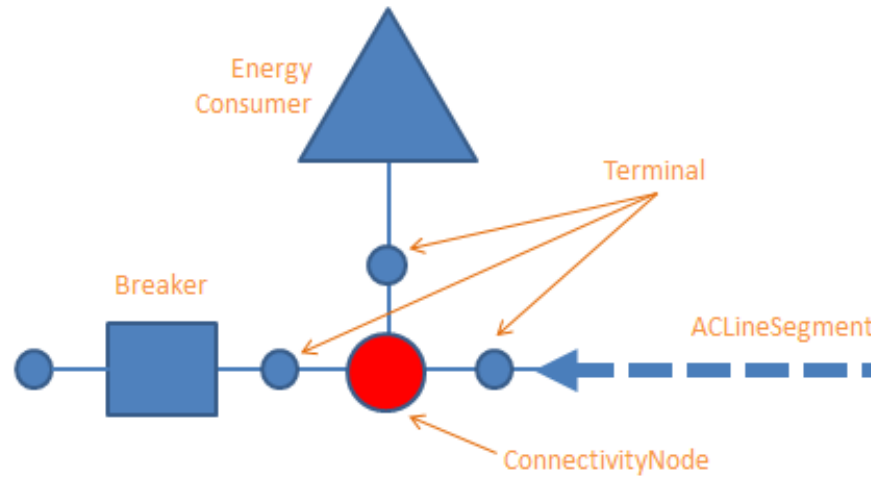


Main application contexts

- Standardized representation of electrical networks topology
- Management of the electrical market
- System integrations at Utility level



Representation of electrical components and their interconnections



Example of a representation of a distribution grid

▲ [PowerTransformer] MV/LV Power Transformer - Substation B2

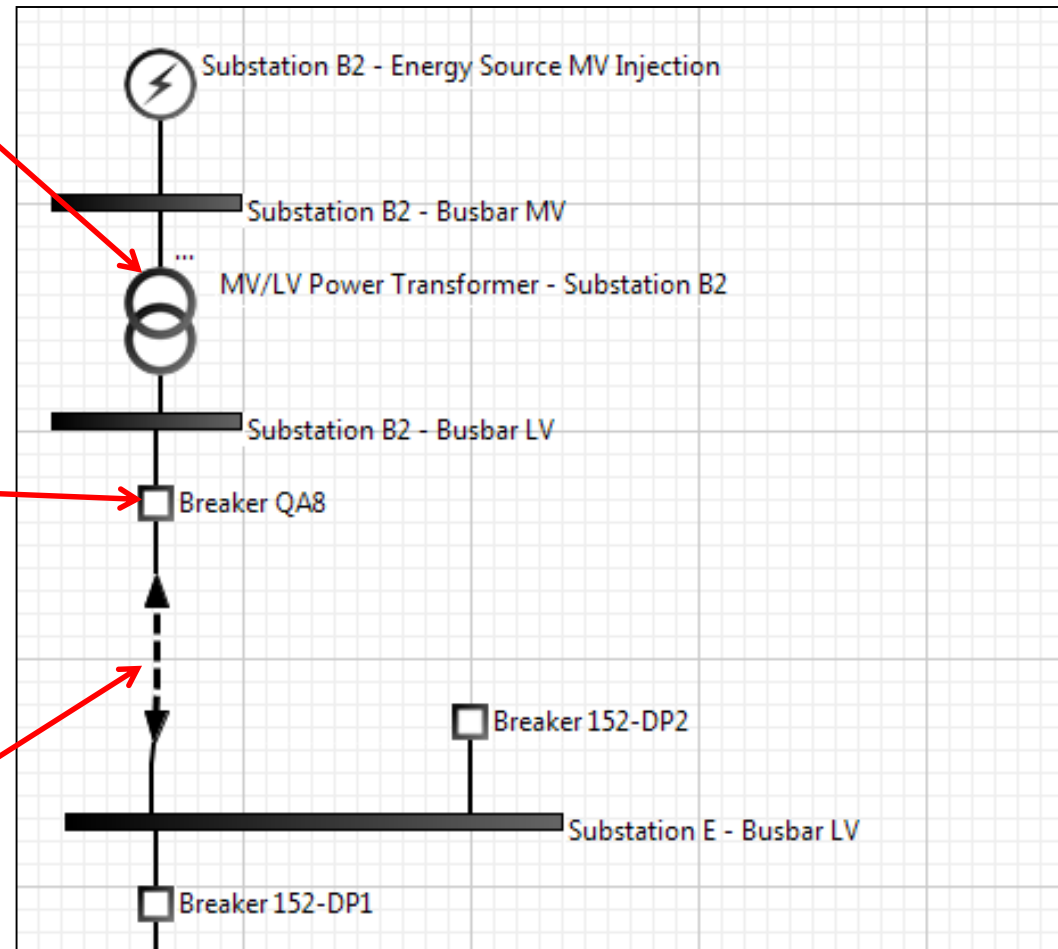
- Str name = MV/LV Power Transformer - Substation B2
- Bn normallyInService = true
- Str vectorGroup = Dyn11
- DiagramObjects (1)
- Location (1)
- EquipmentContainer (1)
- Terminals (2)
- PowerTransformerEnd (2)
 - [PowerTransformerEnd] MV/LV Substation Secondary
 - [PowerTransformerEnd] MV/LV Substation Primary

▲ [Breaker] Breaker QA8

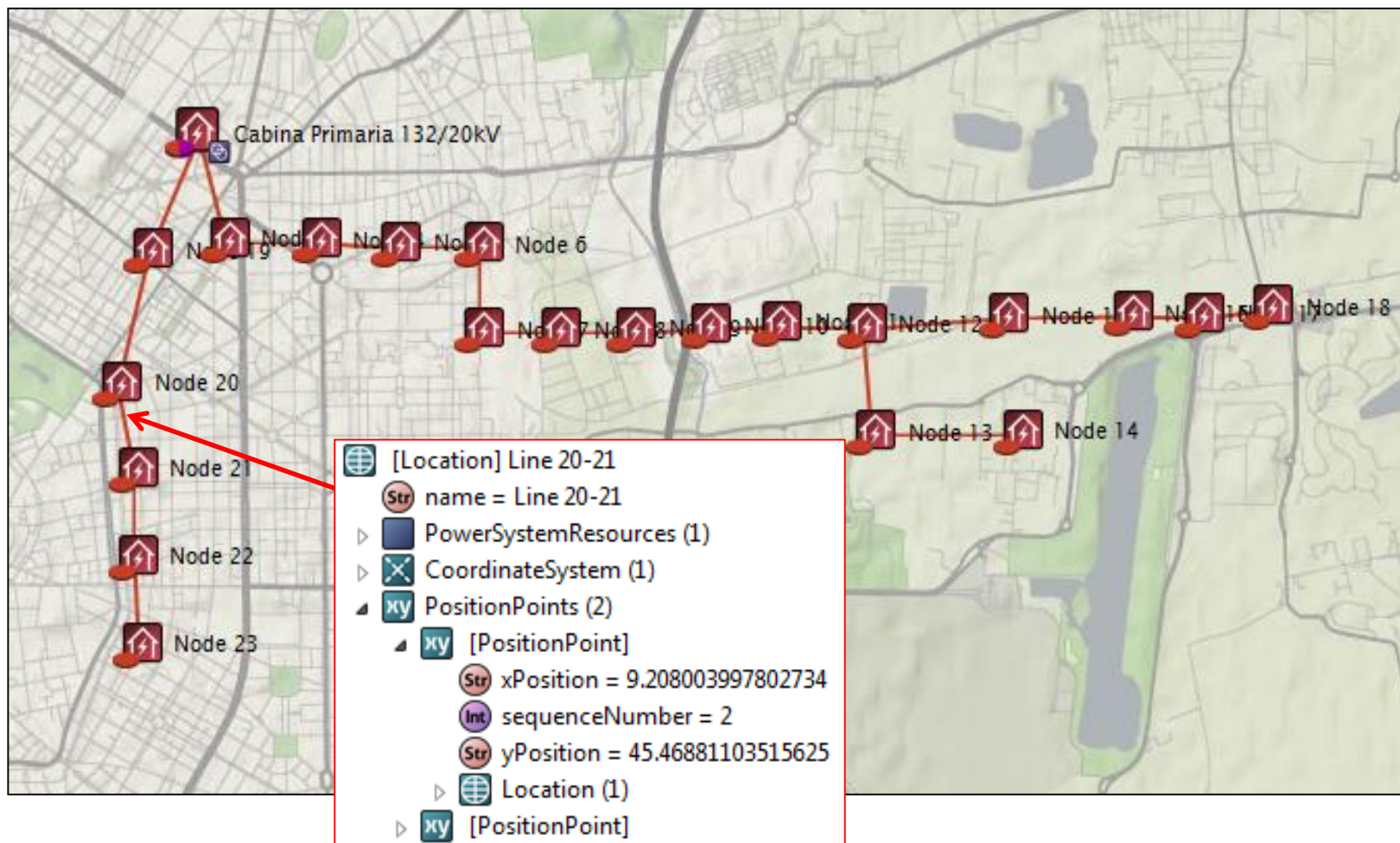
- Str name = Breaker QA8
- Bn normallyInService = true
- Bn normalOpen = false
- Flt ratedCurrent = 800.0
- Flt breakingCapacity = 50000.0
- DiagramObjects (1)
- Terminals (2)

▲ [ACLineSegment] ACLine "B2-E Substation connection"

- Str name = ACLine "B2-E Substation connection"
- Flt length = 14.0
- Flt r = 0.0
- Flt x = 1.0E-7
- Flt bch = 0.0
- DiagramObjects (1)
- Assets (1)
- Location (1)
- OperationalLimitSet (1)
- EquipmentContainer (1)
- BaseVoltage (1)
- Terminals (2)



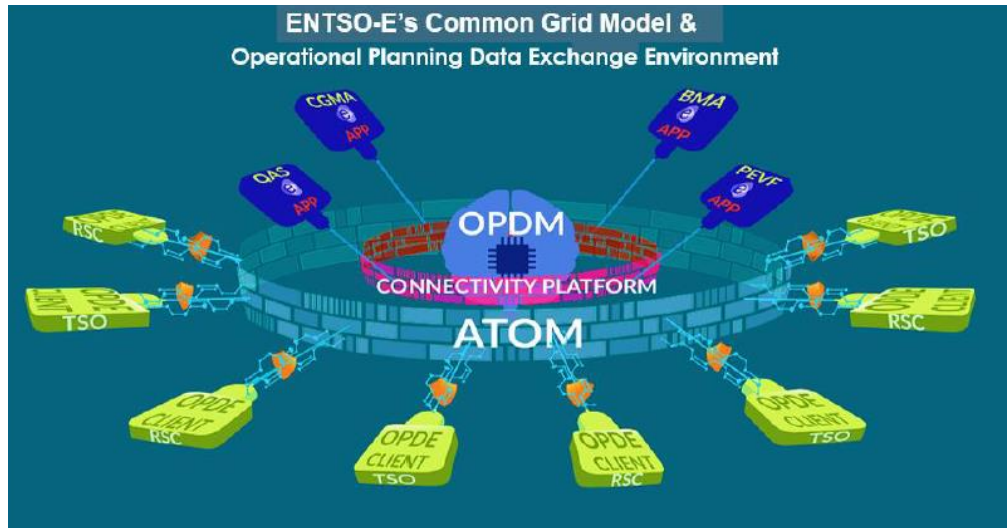
Geographical representation of grid



Current use and perspectives of CIM for electrical networks representation

- Today CIM is used by ENTSO-E to facilitate the exchange of operational and grid planning data among transmission system operators.
(<https://www.entsoe.eu/major-projects/common-information-model-cim/>)
- It is required to implement a series of European network codes including the one on capacity calculation and congestion management and the one on system operation.
- In the future this approach could be applied for information exchange between transmission and distribution system operators

Operational Planning Data Environment Data Hub for system operation



“The Operational Planning Data Environment (OPDE) is the information platform that will support the CGM (CIM based), allowing TSOs and RSCs to communicate. It is also the software basis for running the five core services of RSCs related to network codes implementation”.
(source: [ENTSO-E annual work programme 2018](#))

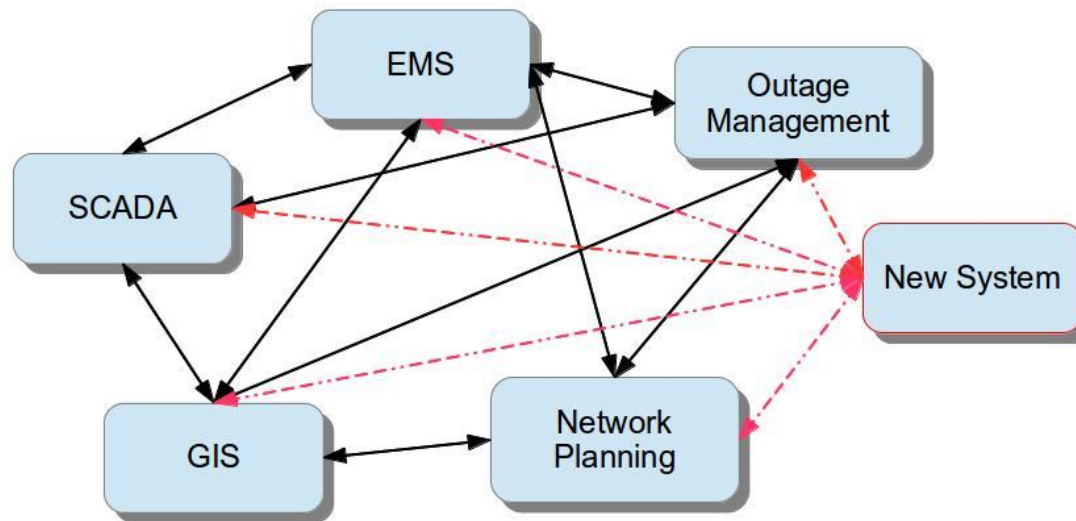
Extension of the CIM Model for the management of the energy market

- The native CIM Model, specified by IEC61970-301 and IEC61968-11, was extended using the definition of classes necessary to implement the energy market management.
- This extension, which is specified by IEC62325-301, is composed by three classes set, or packages:

MarketCommon	(Stakeholders involved in the electrical exchange)
MarketManagement	(European Market Model)
MarketOperations	(US market Model)

CIM for Utility system integrations

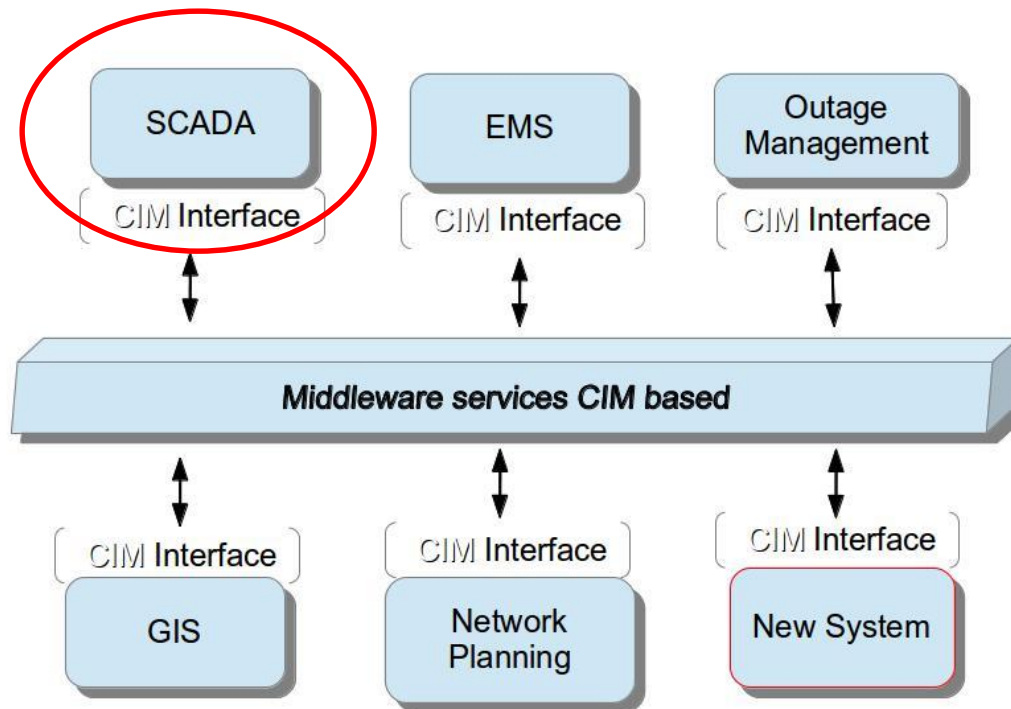
Different software applications use the same information



Every new application/system has to develop $(n-1)$ interfaces

CIM for Utility system integrations

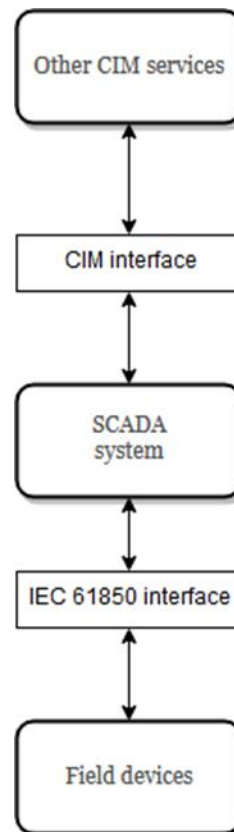
CIM represents the common semantic reference model for different applications



Every new application has to develop only one standard interface

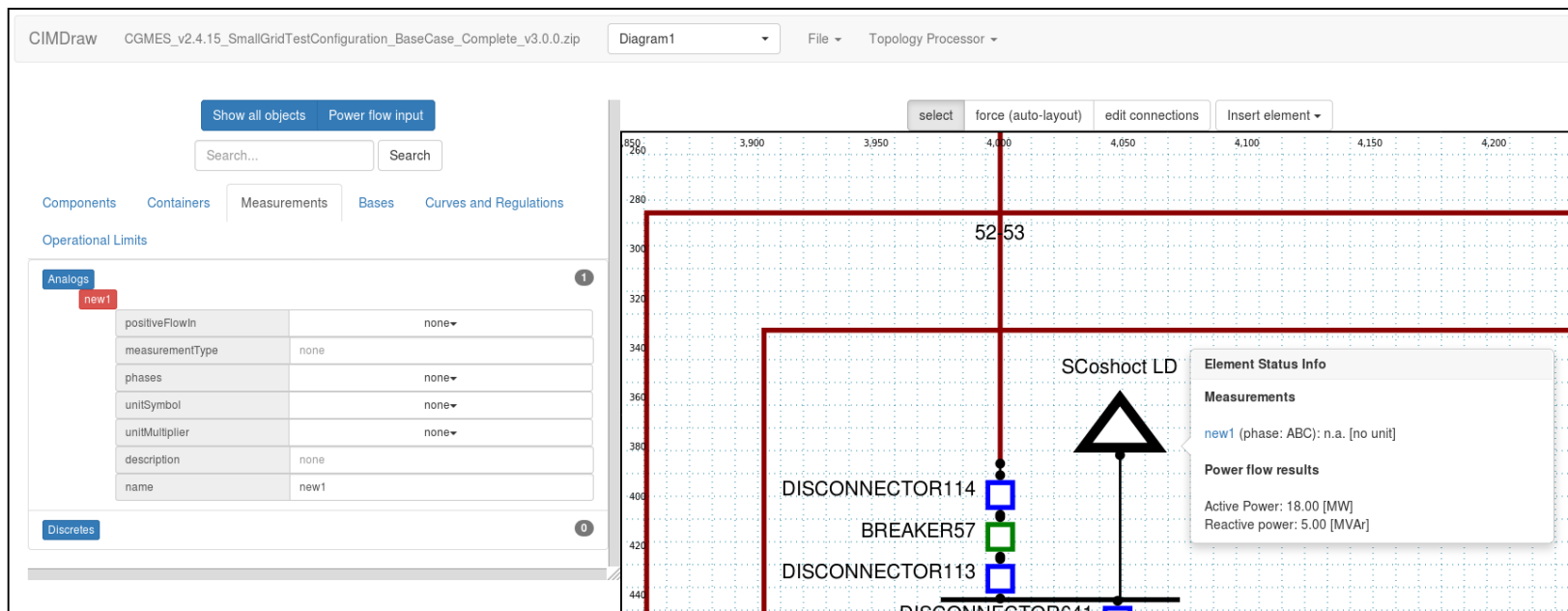
ERIGrid context (1)

A first proposal for the SCADA interface has been made as IEC 61970-451 some time ago, but a final standard is far from finalization for now. However, the high level principles defined in that standard have been used in ERIGrid.

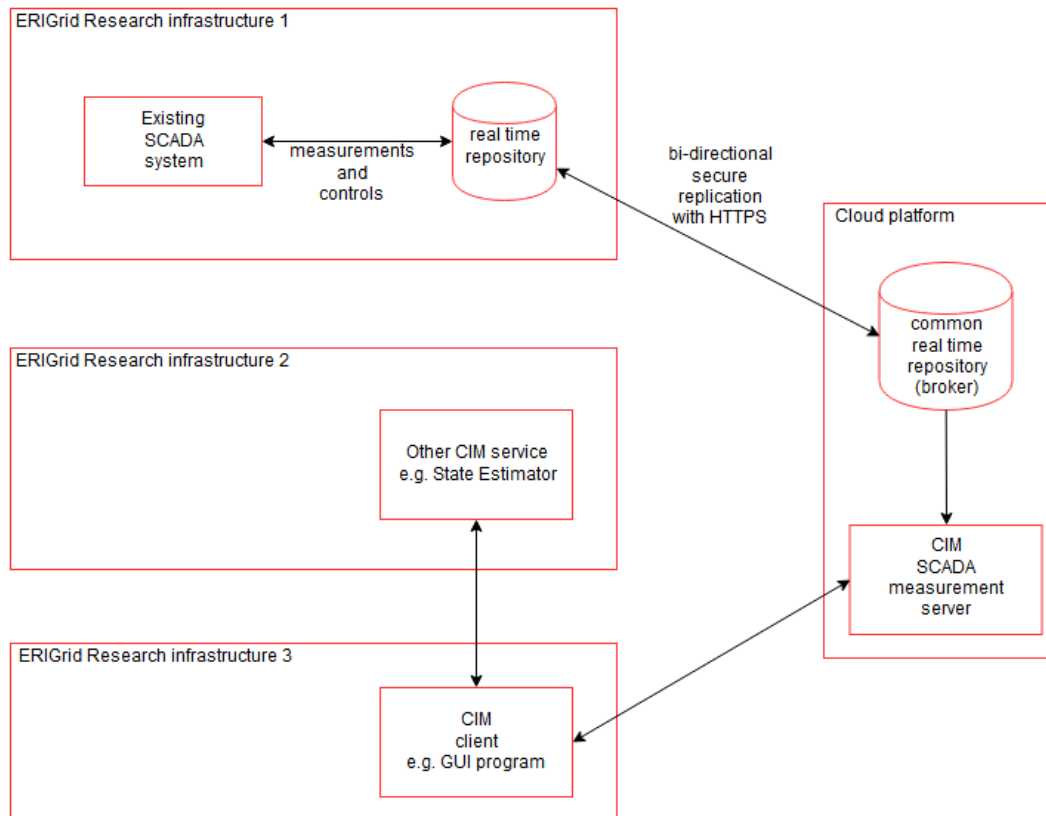


ERIGrid context (2)

The final objective is to demonstrate the use of high level CIM services by different project partners. One service is the SCADA, another one can be a state estimator. The overall orchestration and visualization will use the open source tool **CIMDraw** which can be downloaded here: <https://goo.gl/q93kTt>



ERIGrid context (3)



Different CIM services could be provided by each partner, thus implementing a kind of **distributed service oriented architecture**.

Conclusions

The development of the Smart Grid needs the integration of many heterogeneous systems

IEC 61850 and CIM can help with standardized semantics, but there are still open issues and ongoing developments

The ERIGrid project applies these standards on top of a “virtual bus” integrating research infrastructures

The JaNDER layered approach allows for a gradual and meaningful adoption of the two standards

The adoption of open source software allows for a wider use, testing and critical review of the proposed solutions