6th UCAAT User Conference on Advanced Automated Testing

ETSI


# PROOF OF CONCEPT FOR MODEL-BASED TESTING OF IEC 61850 SMART GRID USING TTCN-3 & UML


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# Agenda

- Smart Grid & the interoperability challenge
- Model-Based Automated Conformance testing of IEC 61850
- Lessons Learned, Future Actions and Summary

# Smart Grid

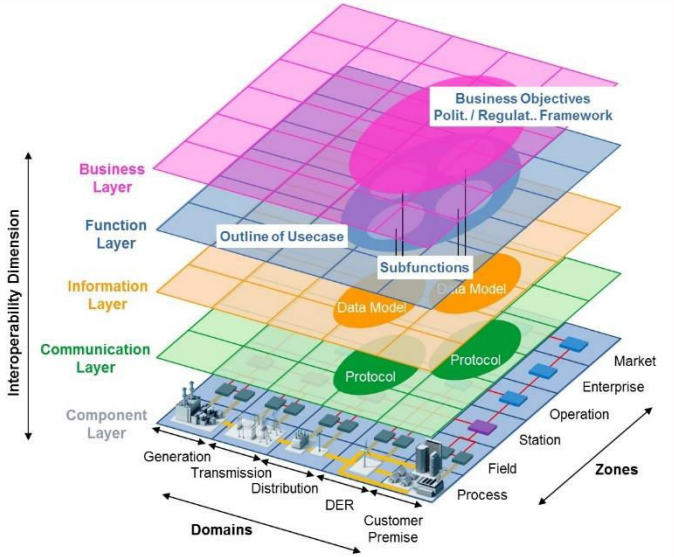
A disruptive answer to the **environmental** and **economics needs** of future electricity supply

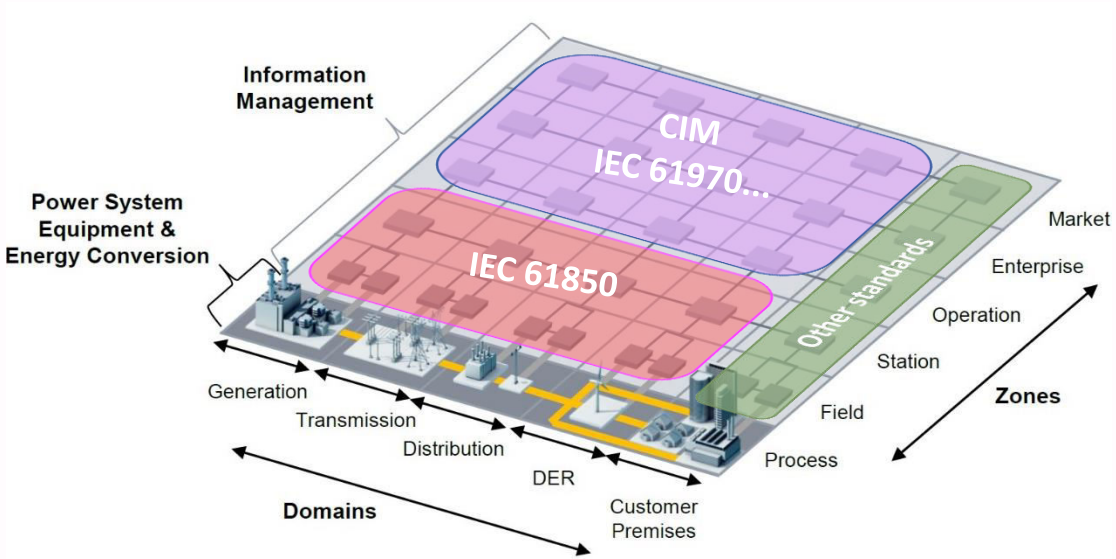
Image from Schneider Electric

| Reliability | Flexibility | Sustainability | Efficiency | New Markets |
|---|---|---|---|---|
| • Automatic Fault detection & self-healing mecanisms<br>• Improved security | • Easier reconfigurations<br>• Handling of bidirectional flow<br>• Distributed generation, storage, consumption | • Integration of large-scale renewable energy systems (Wind, Solar, ...)<br>• Reduced operations and management costs | • Demand-side management<br>• Load balancing<br>• Time of use pricing<br>• Reduced peak demand | • Systematic and flexible communication between suppliers/consumers<br>• Platform for advanced services |

# Smart Grid

A multi-domain multi-actor complex system relying on **standardization** and **interoperability**

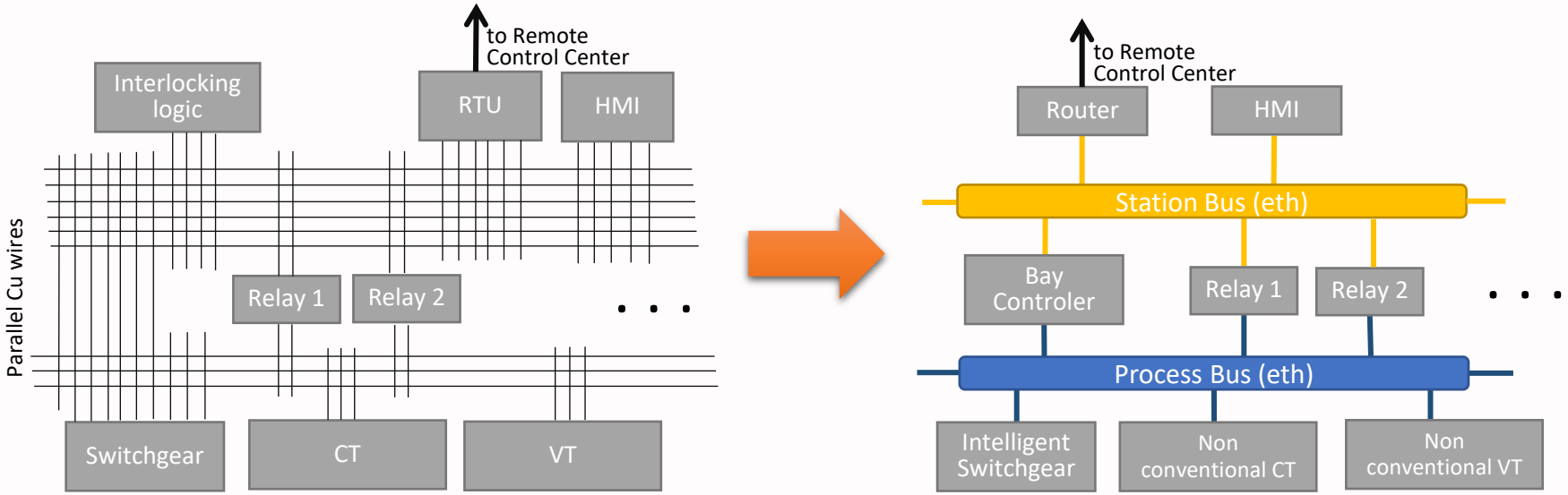



Images from CEN-CENELEC-ETSI Smart Grid Coordination Group – SGAM - 2012

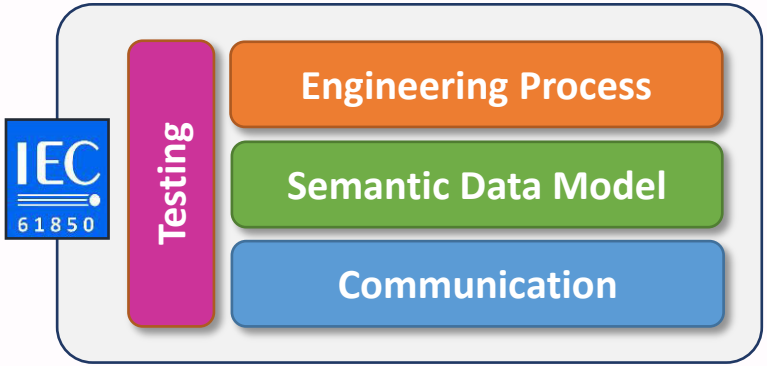
# Digital electrical substation

From **hardwired** to **full digitalized**

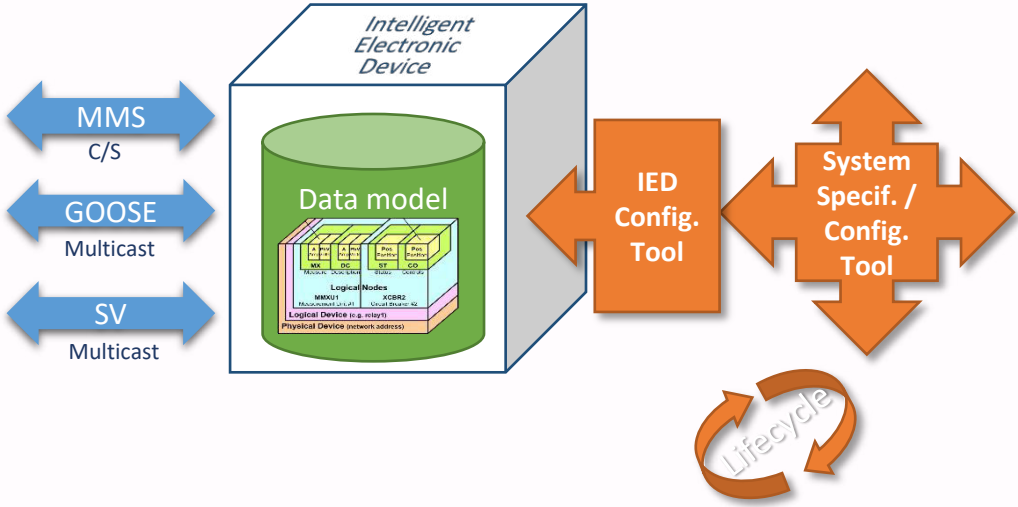


# Digital electrical substation

## The **IEC 61850** International Standard



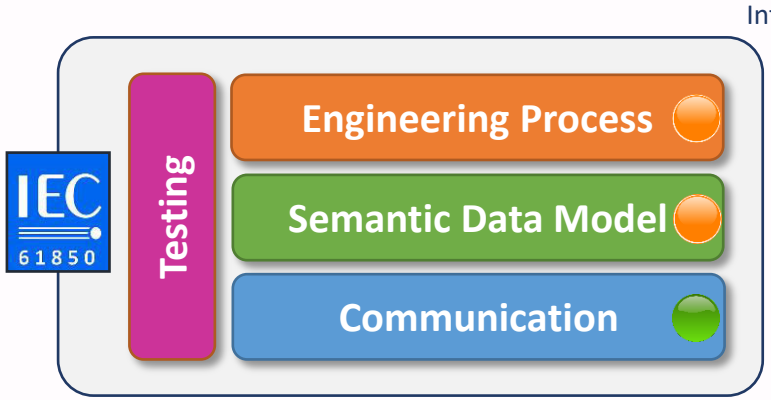

IEC 61850 Goals
- ➔ Interoperability
- ➔ Free configuration
- ➔ Long term stability



# Interoperability challenge / IEC 61850 status

How IEC 61850 provides (a certain level of) **interoperability**

- Diversity of energy generation (nuclear, hydroelectric, PV, Wind, ...)
- Different national traditions of building and managing electrical generation and transmission (20th century paradigm)
- Several device vendors
- Several ways to combine devices into a system




Interoperability status (at the moment)

Lots of options
System/IED config.

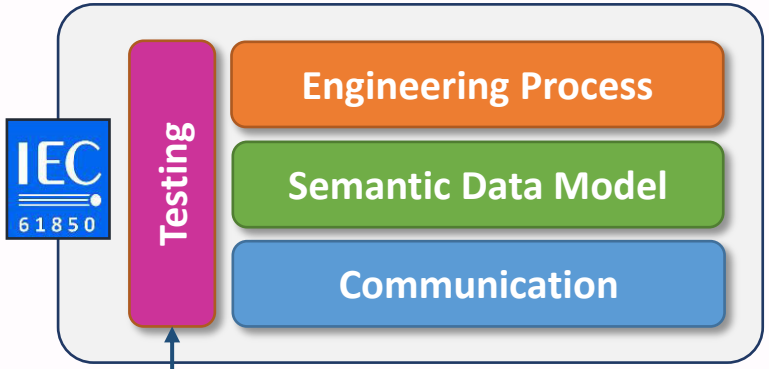
Lots of options
Partial implementation

Good

# IEC 61850 conformance testing

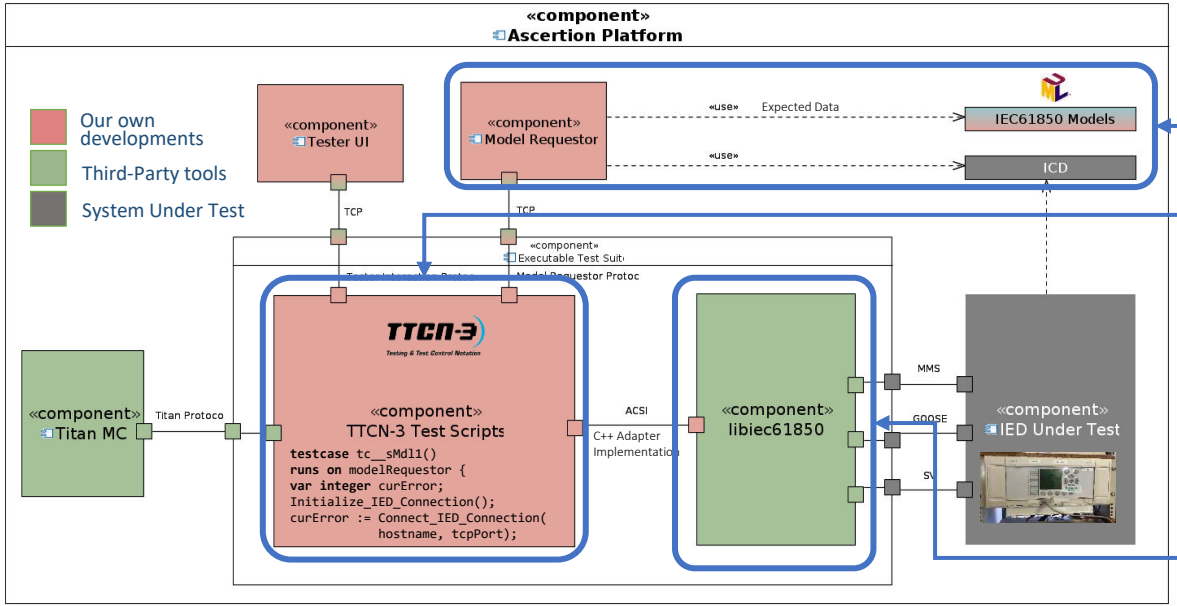
The challenge to manage **tremendous volume** of **reference data**

- 650 test procedures (UCA)
- Mainly assert the two first levels of interoperability : protocol/API communication and data model
- Single IED black-box testing
- Challenge : reference data are an evolving 4000+ pages body of knowledge !
- Approuved worldwide certifiers: only 10 level A and 4 level B



# Model-based testing platform

## Overview



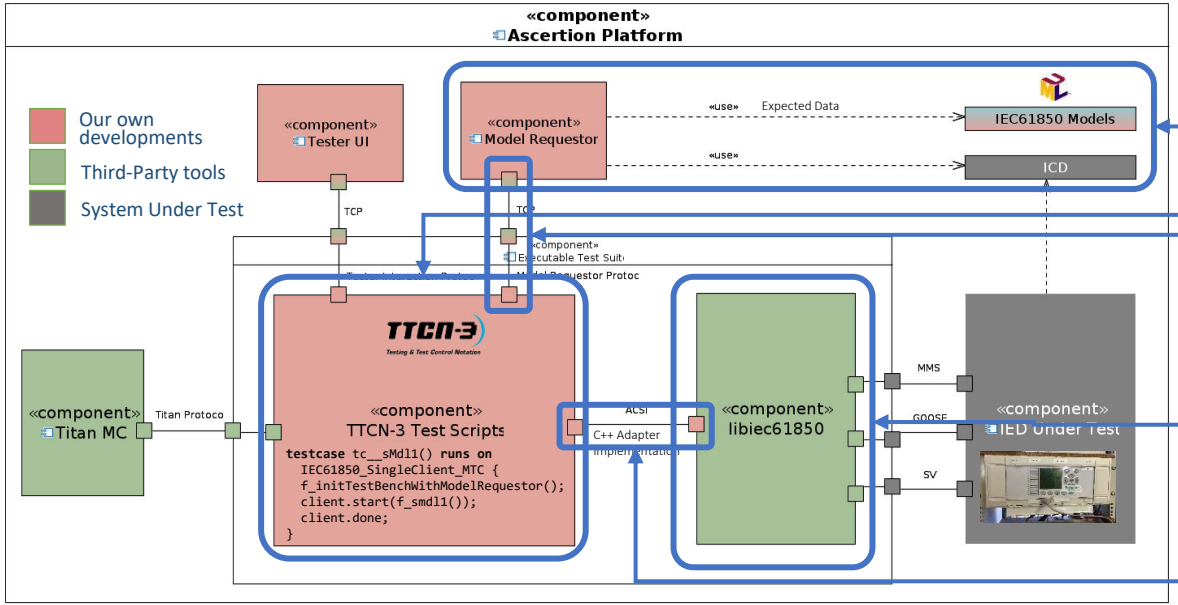

**Model-Based Oracle** : model server answers requests from test procedures asking for expected data (also IED config. data from ICD file)

**Test Procedures :** implemented test specification, without any hard-coded expected data

**Low level communication stack :** Implemented API/protocol

# Model-based testing platform

## Separation of concerns to provide **flexibility**




**User domain**

**Tester domain (close to user domain)**

Request/Response Tester protocol implementation (TTCN-3 port)

**Communication domain**

User/Tester protocol (ACSI) on top of lower MMS protocol (TTCN-3 port)

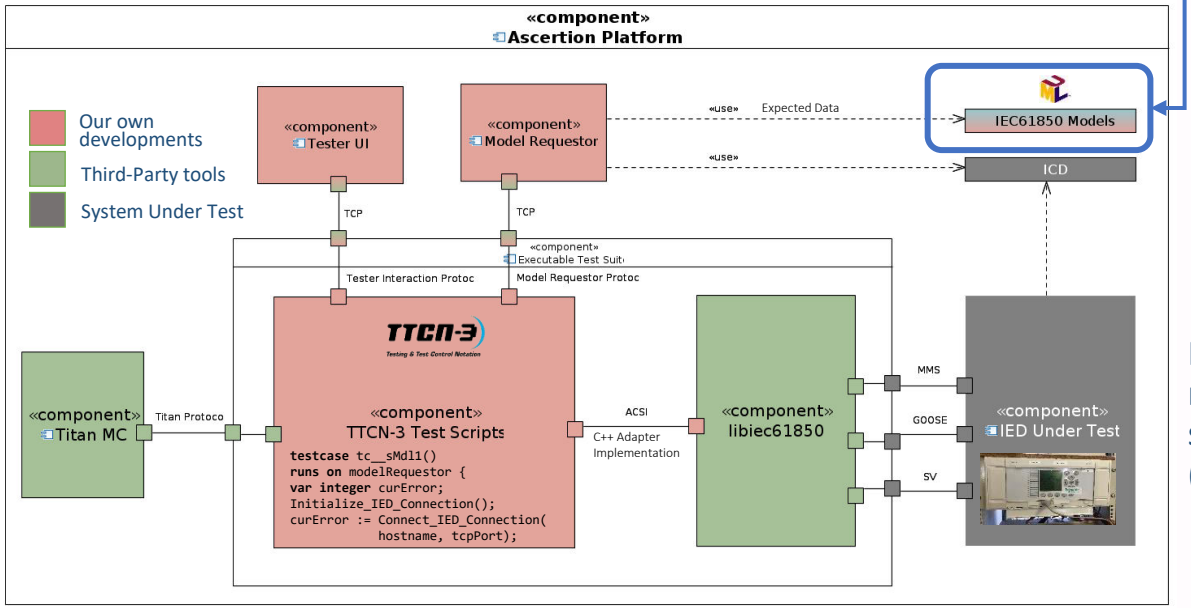
**Low coupling, no "spagetthi effect"**

**Different change forces**

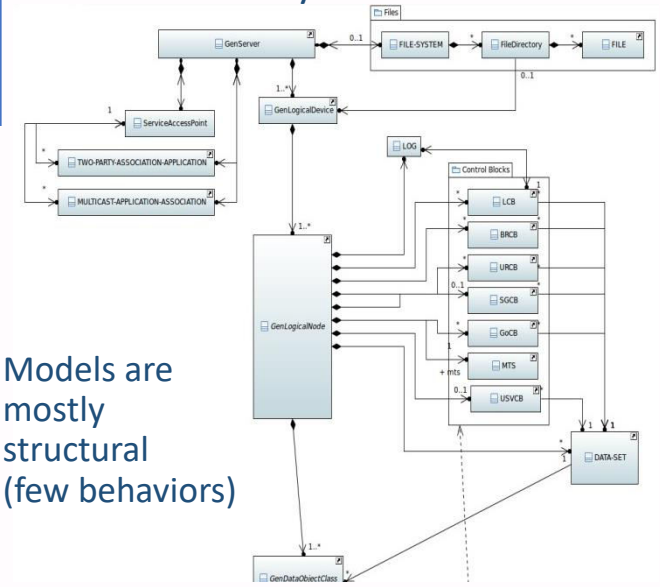
**Different separate skills (needed to maintain/evolve the system)**

# Model-based testing platform

## UML models to adress the « **reference challenge** »

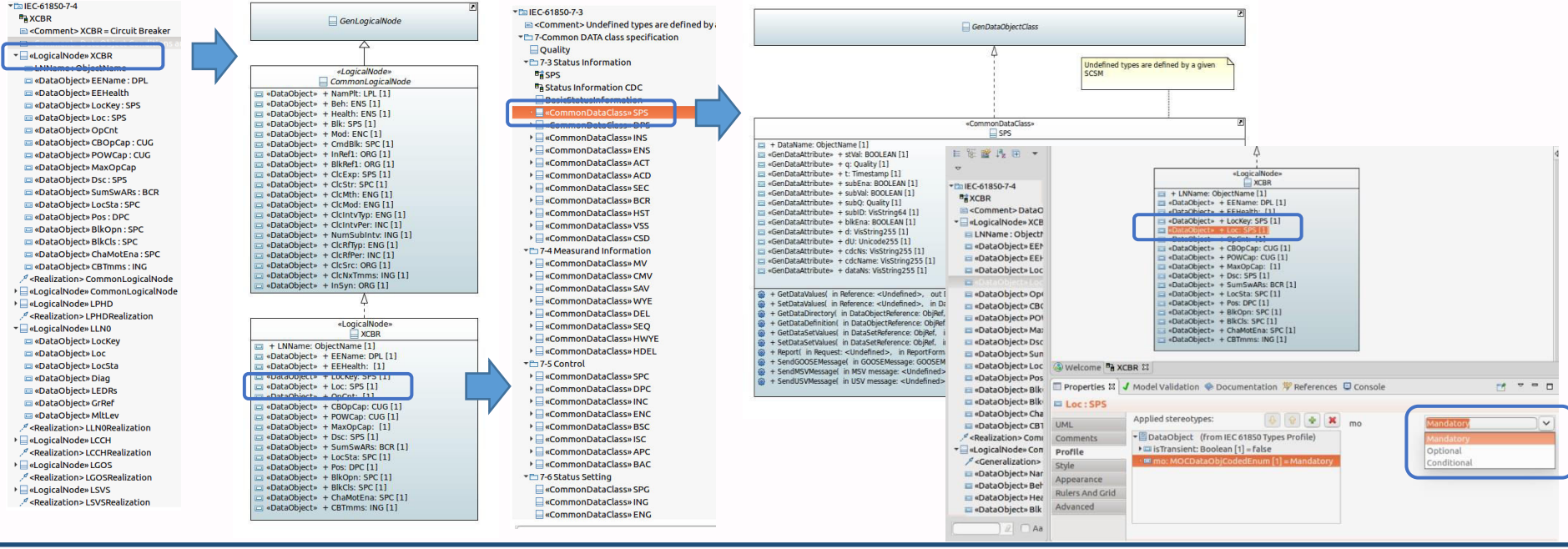



First : manually made models




Models are mostly structural (few behaviors)

# Model-based testing platform : models excerpts



# Model-based testing platform : hybrid models

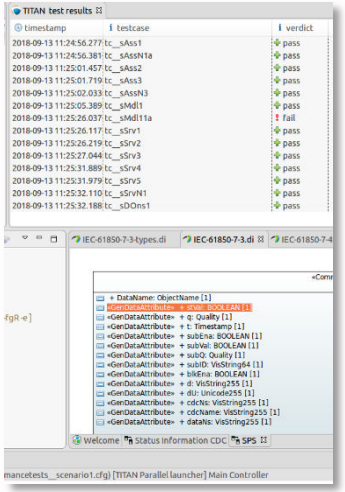
From **manual** creation to **automated** models generation

- Manual modeling weakness
  - **Too much data** to cope with (hundreds of classes with douzains of complex attributes)
  - **Error** prone task

- Solution : parse the “machine processable” NSD files that will be officially published by IEC (Ed 2.1 of the Standard)
  - **Automatically fill** the relevant parts of our manual models with **generated data**
  - Error probability drastically reduced

# Results / Lessons learned

- Proof of Concept is validated
  - Several test cases ran successfully on a real IED
- “Model friendly” standards (increasingly common within the energy industry) authorizes fruitful MBT approaches
  - Improve understandability, fault analysis, learning
  - Automatizability made (easy) less difficult
  - Facilitate test campaign configuration




# Results / Lessons learned

- High initial effort to understand and model the standard (but one shot)
- Critical decision : where to stop modeling and to start implementing ?
  - Protocol service signatures are defined in TTCN-3 not in UML models
- TTCN-3 is very pertinent for MBT
- Lack of TTCN-3 object orientation is sometimes painful (not easy to interface with hierarchical models)

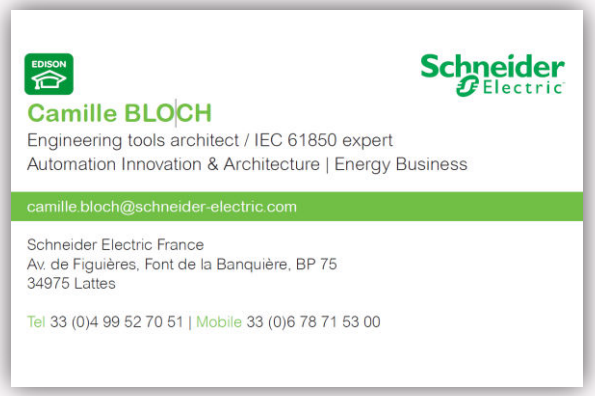
# Future actions & Challenges

- Implement more test procedures
- Develop adapters for the other IEC 61850 communication protocols (GOOSE, SV)
- Test several IEDs interacting : automatize the forthcoming Basic Application Profile (IEC 61850 Ed2.1) trough model aware system testing
- Use our approach for other “model friendly” standards

# Summary

- Validated proof of concept for a model-based conformance testing platform
  - Hybrid modeling : manual + automatic is fruitful with “model friendly” standards
  - Separation of concerns using model-based oracles improves flexibility
- Easily adapt to standard evolutions : model change, protocol change, test specification change
- Maintenance/evolution easier thanks to a clear separation of the skills involved

# Thank you for your attention – Questions / Answers



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