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

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L C I E

**Schneider**  
Electric

# 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



## Reliability

- Automatic Fault detection & self-healing mechanisms
- Improved security

## Flexibility

- Easier reconfigurations
- Handling of bidirectional flow
- Distributed generation, storage, consumption

## Sustainability

- Integration of large-scale renewable energy systems (Wind, Solar, ...)
- Reduced operations and management costs

## Efficiency

- Demand-side management
- Load balancing
- Time of use pricing
- Reduced peak demand

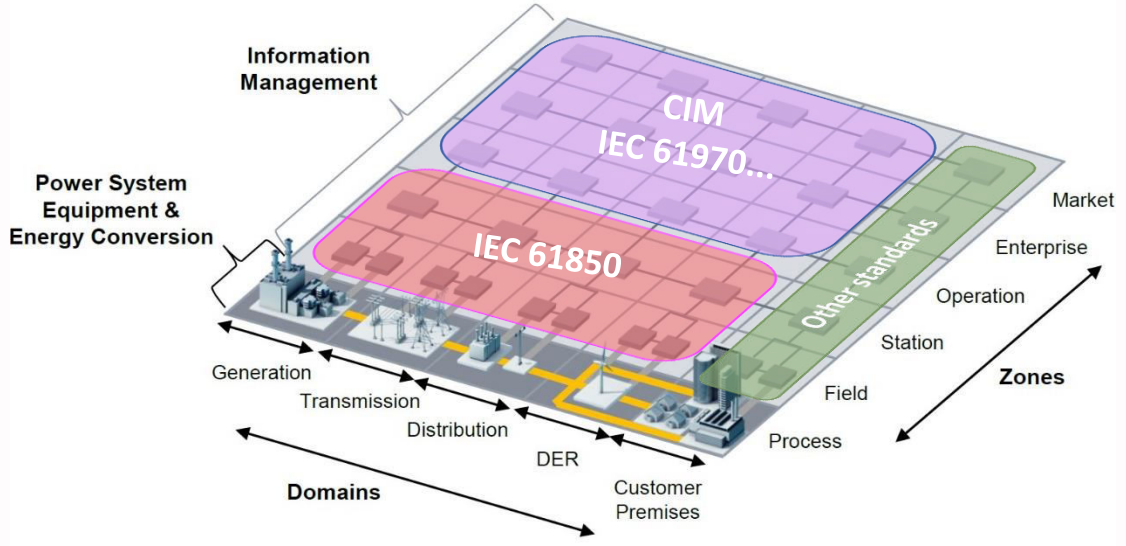
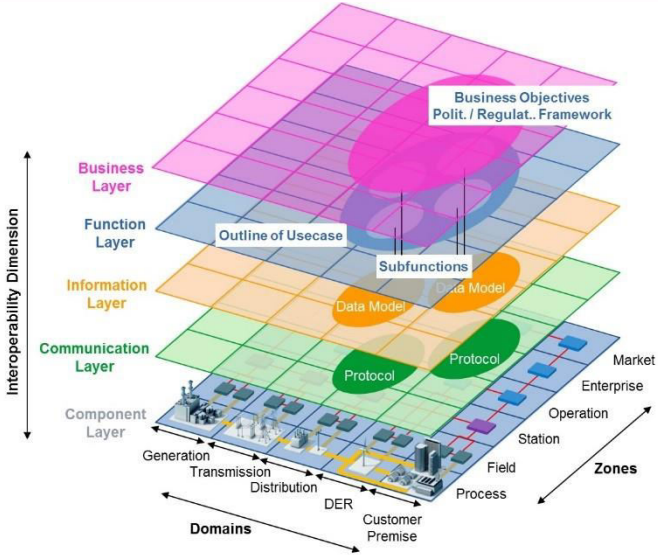
## New Markets

- Systematic and flexible communication between suppliers/consumers
- Platform for advanced services

Image from Schneider Electric

# Smart Grid

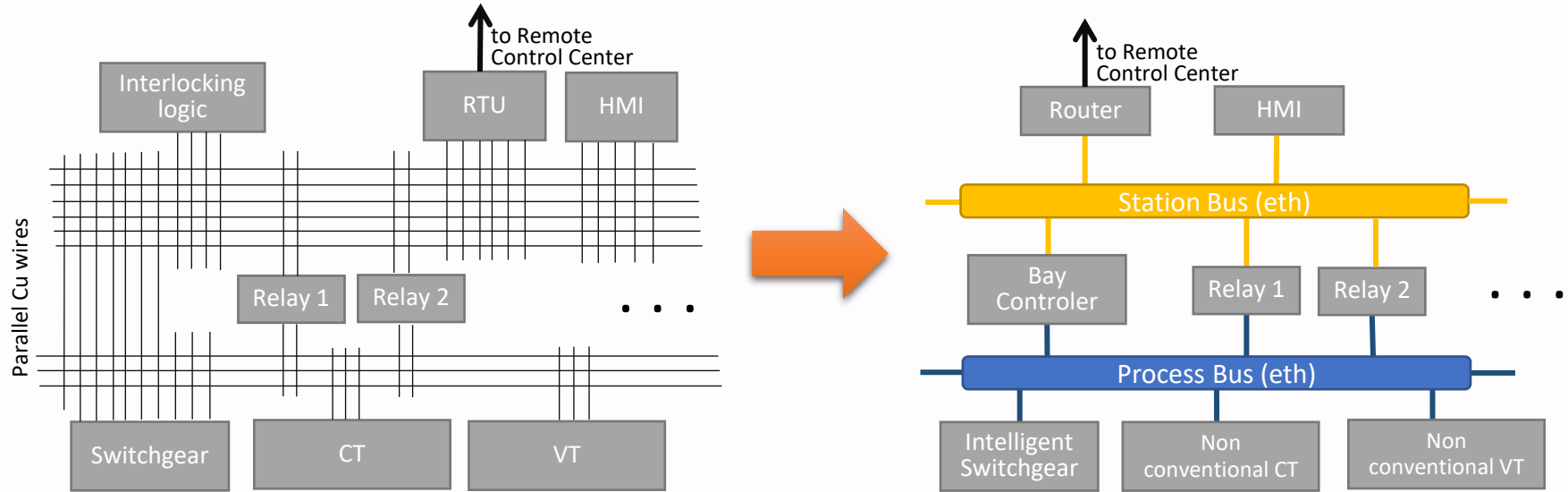
A multi-domain multi-actor complex system relying on **standardization** and **interoperability**



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

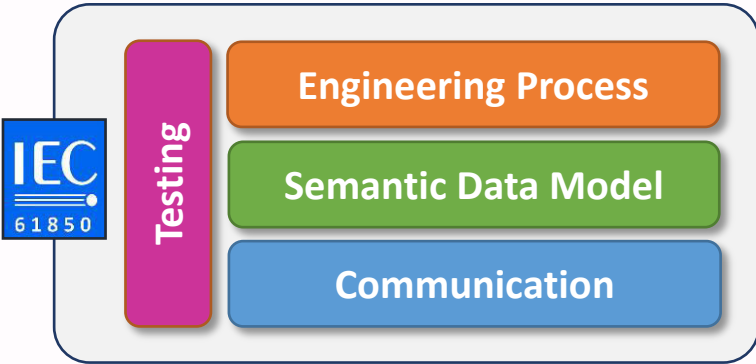
# Digital electrical substation

From hardwired to full digitalized

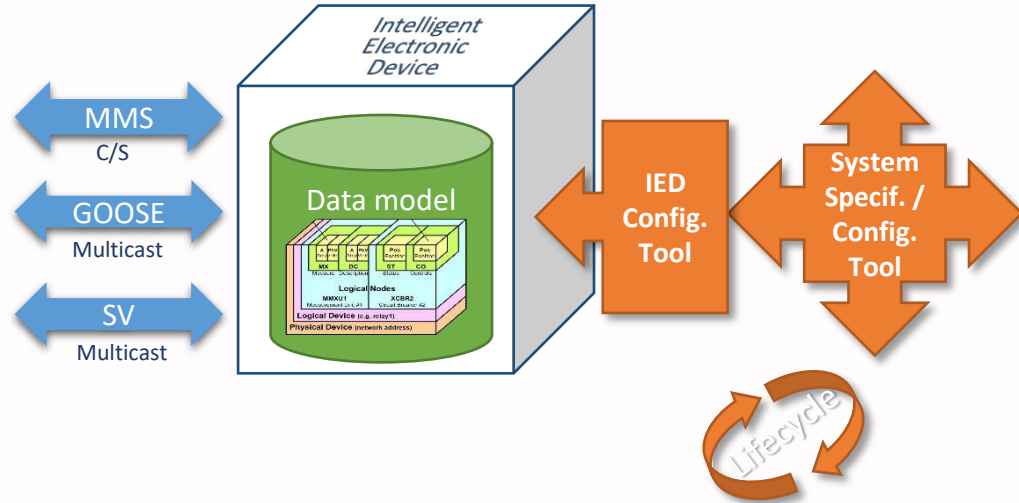


# Digital electrical substation

The IEC 61850 International Standard



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

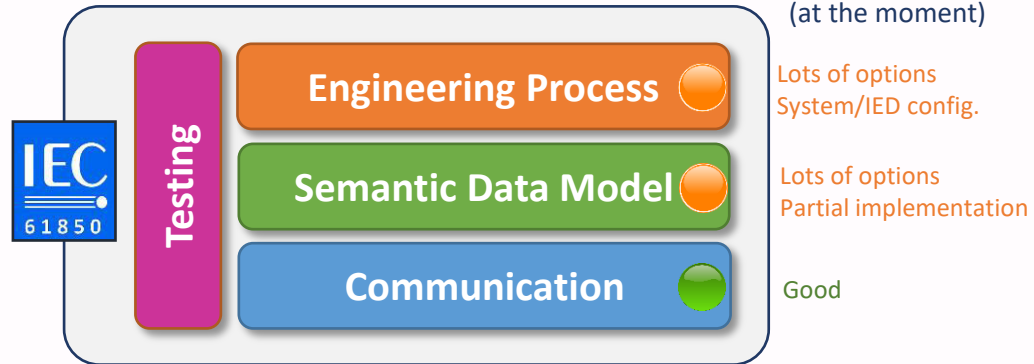




# Interoperability challenge / IEC 61850 status

How IEC 61850 provides (a certain level of) interoperability

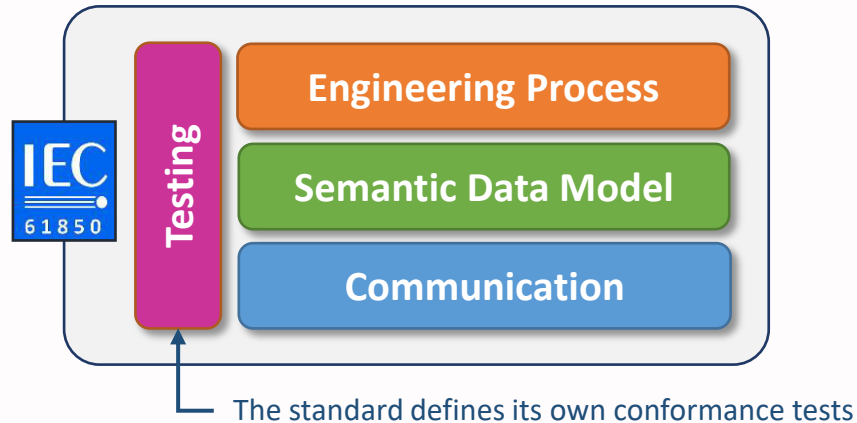
- Diversity of energy generation (nuclear, hydroelectric, PV, Wind, ...)
- Different national traditions of building and managing electrical generation and transmission (20th century paradigm)
- Several device vendors
- Several ways to combine devices into a system



# IEC 61850 conformance testing

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

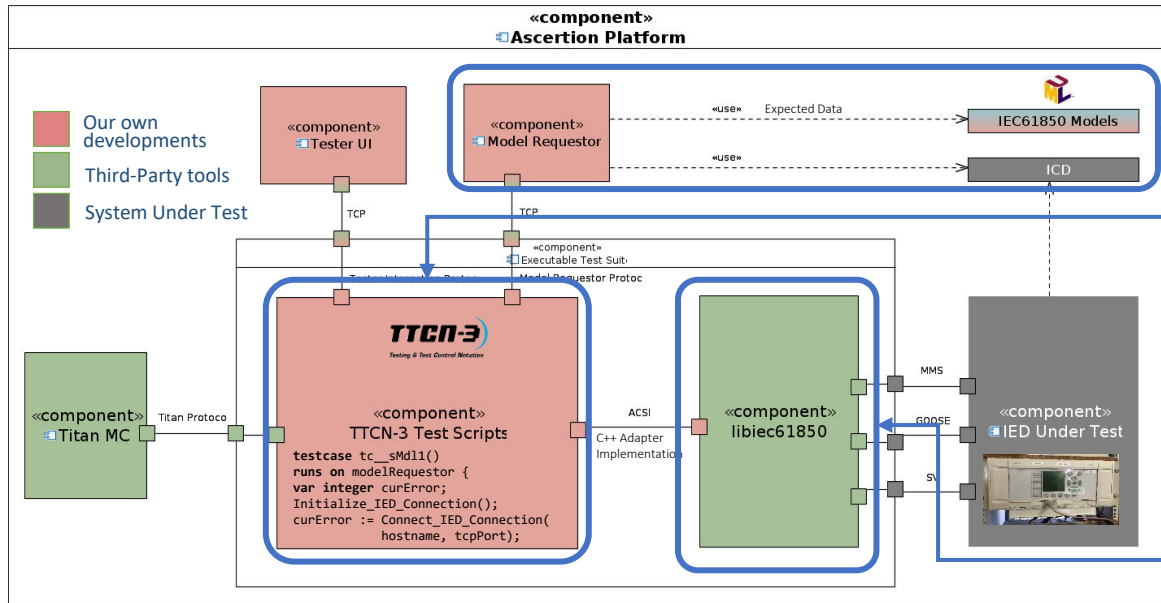
- 650 test procedures (UCA)
- Mainly assert the two first levels of interoperability : protocol/API communication and data model
- Single IED black-box testing
- Challenge : reference data are an evolving 4000+ pages body of knowledge !
- Approved worldwide certifiers: only 10 level A and 4 level B





# Model-based testing platform

## Overview



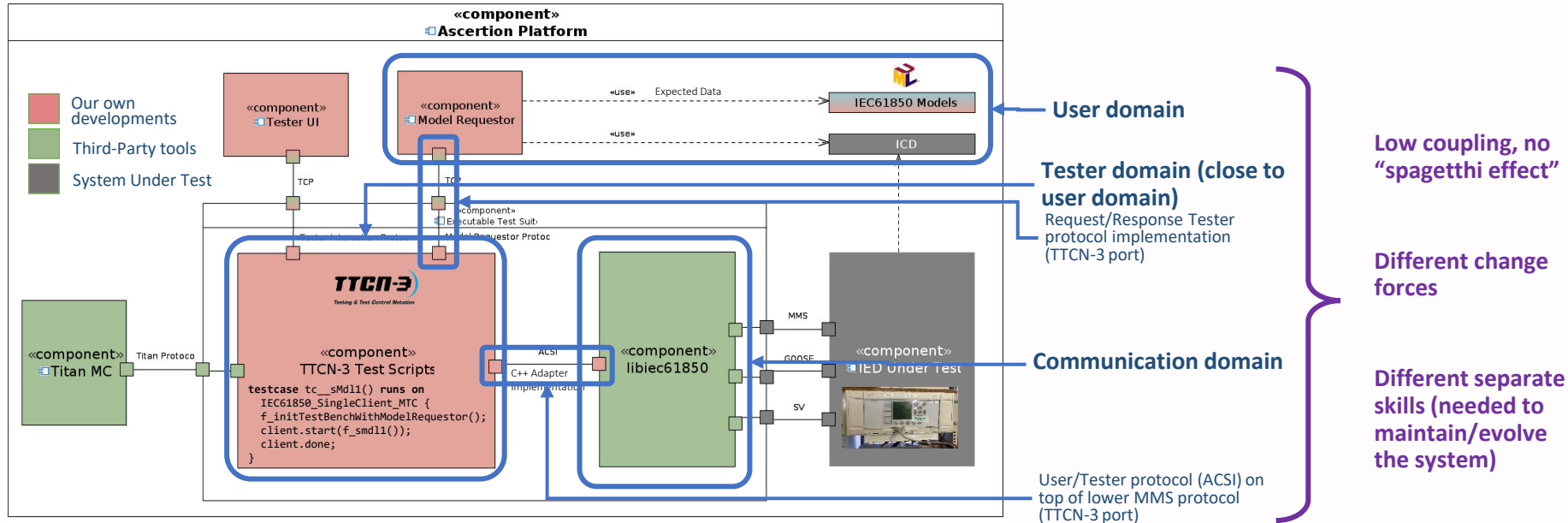
**Model-Based Oracle** : model server answers requests from test procedures asking for expected data (also IED config. data from ICD file)

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

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

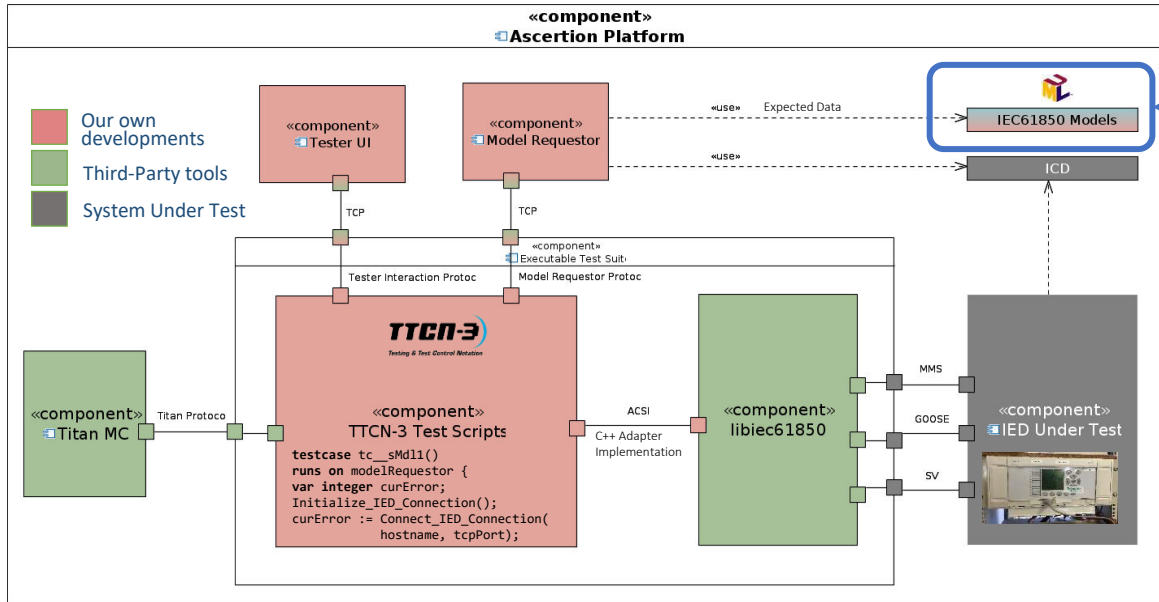
# Model-based testing platform

Separation of concerns to provide flexibility

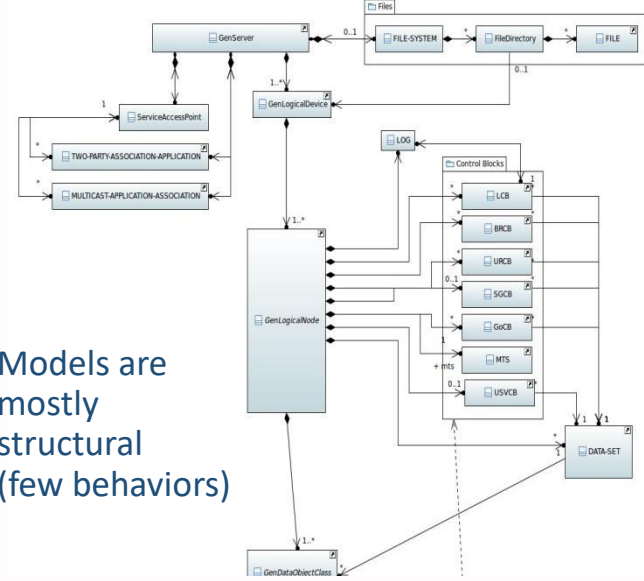


# Model-based testing platform

UML models to adress the « reference challenge »



First : manually made models



Models are mostly structural (few behaviors)

# Model-based testing platform : models excerpts

The image illustrates the model-based testing platform through three interconnected views:

- Left View (Tree View):** Shows the IEC 61850-7-4 model structure. The selected path is: IEC 61850-7-4 > XCBR > LogicalNode XCBR. The tree lists various data objects like EENName, EEHealth, LocKey, etc.
- Middle View (UML Class Diagram):** Displays the class structure for 'LogicalNode XCBR'. It includes a 'CommonLogicalNode' base class and several 'DataObject' subclasses. The 'CommonDataClass SPS' is highlighted, indicating its role in the model.
- Right View (UML Class Diagram):** Shows the 'GenDataObjectClass' hierarchy. It includes 'CommonDataClass' and 'SPS' subclasses. The 'CommonDataClass SPS' is highlighted, showing its inheritance from 'CommonDataClass'.
- Properties Window (Far Right):** Shows the configuration for the selected 'Loc: SPS' element. The 'Mandatory' property is set to 'Mandatory' in a dropdown menu.

# 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 dozens 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

The screenshot shows a software interface with two main panels. The top panel, titled 'TITAN test results [1]', displays a table of test results:

timestamp	testcase	verdict
2018-09-13 11:24:56.277	tc_sAss1	pass
2018-09-13 11:24:56.381	tc_sAss1a	pass
2018-09-13 11:25:01.427	tc_sAss2	pass
2018-09-13 11:25:01.719	tc_sAss3	pass
2018-09-13 11:25:02.033	tc_sAssN3	pass
2018-09-13 11:25:05.389	tc_sMd1	pass
2018-09-13 11:25:26.037	tc_sMd11a	fail
2018-09-13 11:25:26.117	tc_sSrv1	pass
2018-09-13 11:25:26.219	tc_sSrv2	pass
2018-09-13 11:25:27.044	tc_sSrv3	pass
2018-09-13 11:25:31.889	tc_sSrv4	pass
2018-09-13 11:25:31.939	tc_sSrv5	pass
2018-09-13 11:25:32.110	tc_sSrvN1	pass
2018-09-13 11:25:32.188	tc_sD0ms1	pass

The bottom panel shows a tree view of a data object:

```

+ DataName: ObjectName [1]
  +<GenDataAttribute> + q: Quality [1]
  +<GenDataAttribute> + t: Timestamp [1]
  +<GenDataAttribute> + subVal: BOOLEAN [1]
  +<GenDataAttribute> + subID: Quality [1]
  +<GenDataAttribute> + subID: VisString64 [1]
  +<GenDataAttribute> + bInEn: BOOLEAN [1]
  +<GenDataAttribute> + d: VisString255 [1]
  +<GenDataAttribute> + dU: Unicode255 [1]
  +<GenDataAttribute> + cdName: VisString255 [1]
  +<GenDataAttribute> + cdName: VisString255 [1]
  
```





## 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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