

### 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

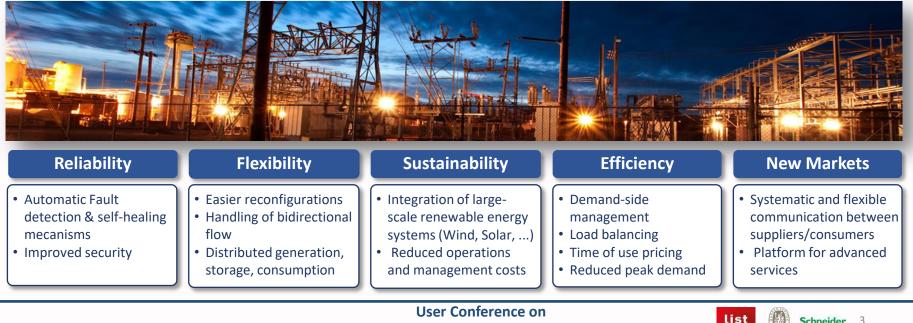






### Smart Grid

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



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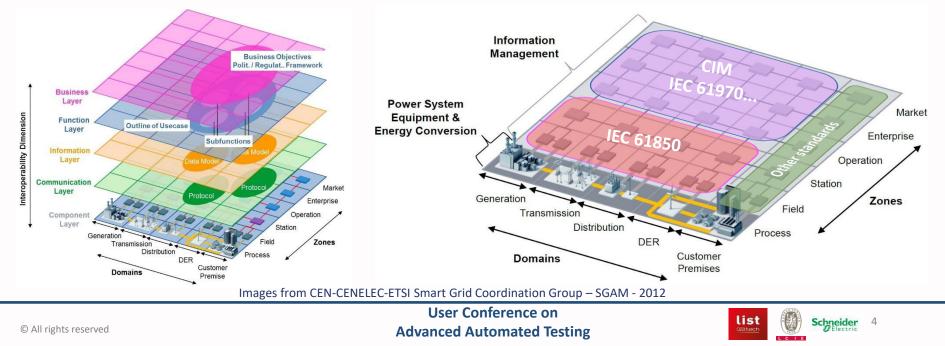
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### Smart Grid

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

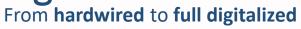


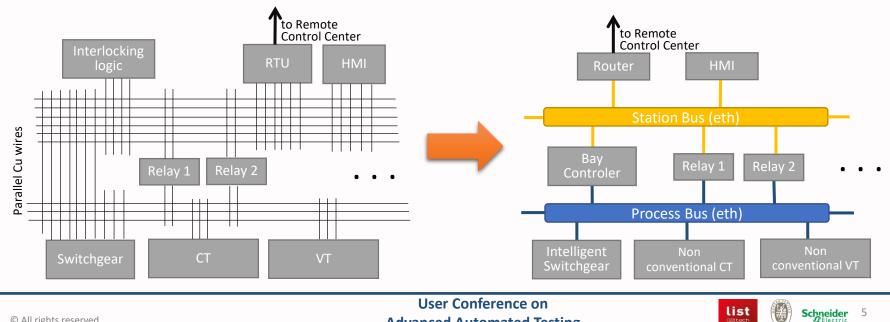




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# **Digital electrical substation**





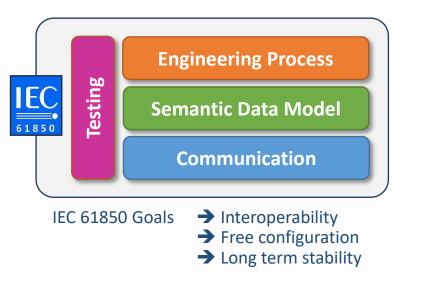
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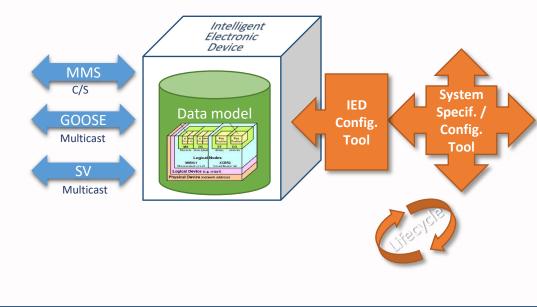




## Digital electrical substation

The IEC 61850 International Standard





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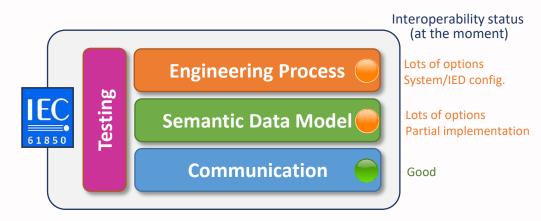




### Interoperability challenge / IEC 61850 status

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





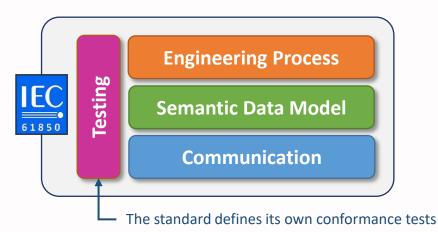




### IEC 61850 conformance testing

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 !
- Approuved worldwide certifiers: only 10 level A and 4 level B



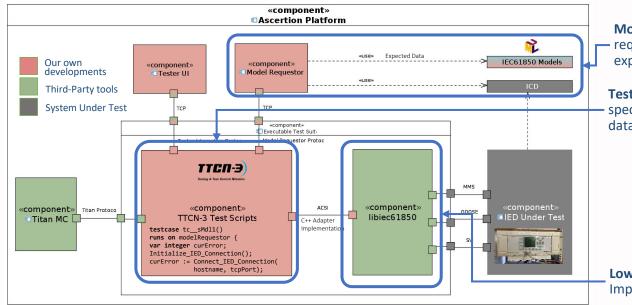








# Model-based testing platform



 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



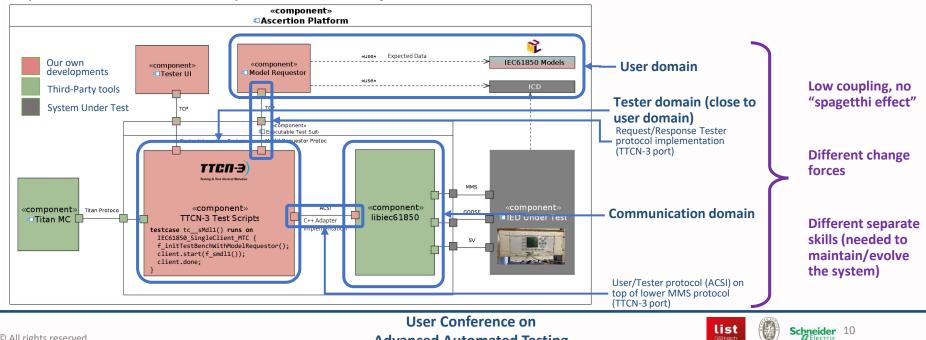
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## Model-based testing platform

Separation of concerns to provide flexibility



**Advanced Automated Testing** 





### Model-based testing platform UML models to adress the « reference challenge »

#### «component» FILE-SYSTEM GenServe Ascertion Platform Y GenLogicalDevice Expected Data ServiceAccessPoint «use» Our own IEC61850 Models «component» «component» developments Model Requestor Tester UI TWO-PARTY ASSOCIATION APPLICATION Control Blocks «use» Third-Party tools MULTICAST-APPLICATION-ASSOCIATIO LCB System Under Test TCP TCP BRCB «component» URCB Executable Test Suit Tester Interaction Protoc Model Requestor Protoc SGCB GenLogicalNoc GoCB ттсп-э Models are MTS Tenting & Tent Control Notati MMS USVCB mostly «component» «component» ACSI «component» Titan Protoco GOOSE structural TTCN-3 Test Scripts libiec61850 IED Under Test Titan MC C++ Adapter DATA-SET Implementation testcase tc\_\_sMdl1() (few behaviors) runs on modelRequestor { var integer curError: Initialize IED Connection(): curError := Connect IED Connection( hostname, tcpPort);



First : manually made models

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### Model-based testing platform : models excerpts

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### 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

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### 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







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### 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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