



МЕЖДУНАРОДНАЯ
КОНФЕРЕНЦИЯ

ЦИФРОВАЯ ПОДСТАНЦИЯ
СТАНДАРТ IEC 61850

ЦИФРОВИЗАЦИЯ
ЭЛЕКТРИЧЕСКИХ СЕТЕЙ

МОСКВА, 2-4 ИЮЛЯ 2019 ГОДА



МЭК 61850

Тестирование систем автоматизации и управления

IEC 61850

Extend the Testing with Automation and Control

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10 July 2019

- > **P**rotection Testing: lots of improvements in the last 20 years
 - > Tools for Automated Testing
 - > Standardized Test Plans reduced efforts dramatically

- > But what happened in the...

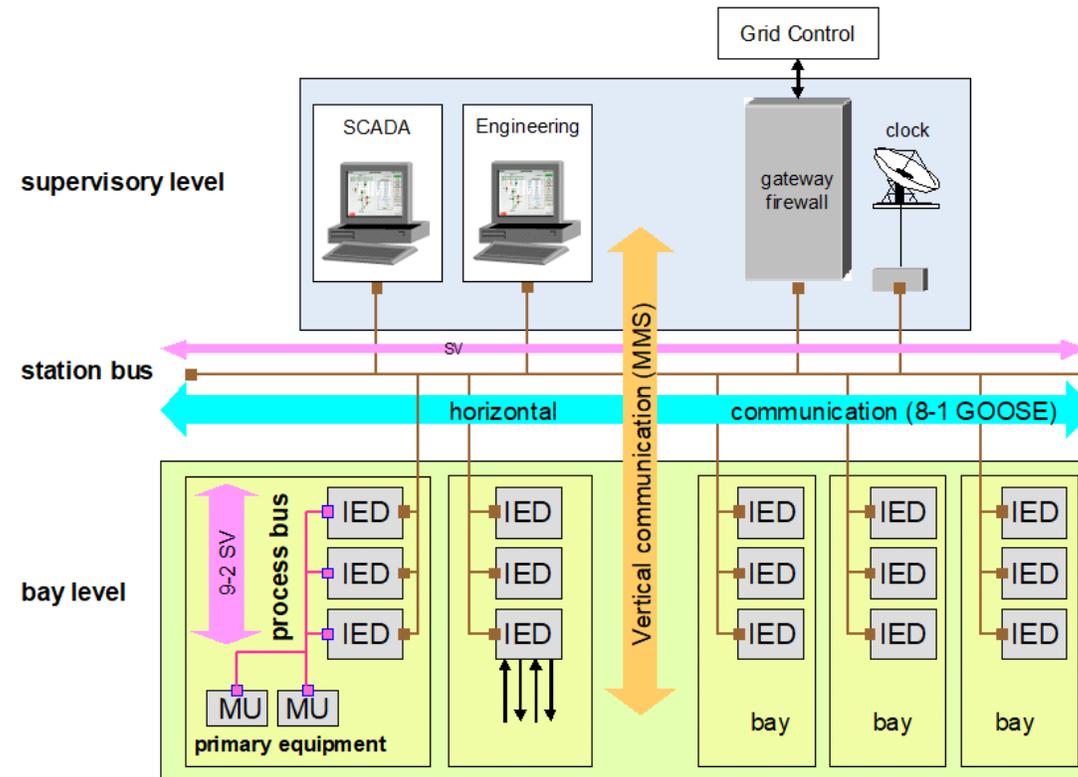
acworld ?

- > Testing **A**utomation and **C**ontrol Systems:
 - > Manual procedures in a Conventional Hardwired Substation
 - > Increase complexity with Communication
 - > Use of Logics, Interlockings
 - > SCADA, Gateways, RTUs
 - > Firmware and Patch Updates due to Cybersecurity requirements

- > Still using the same Manual Testing Methods...

IEC 61850 Substations

- > Data Models
- > Client/Server (Reports), GOOSE, Sampled Values
- > System Configuration Language (SCL)

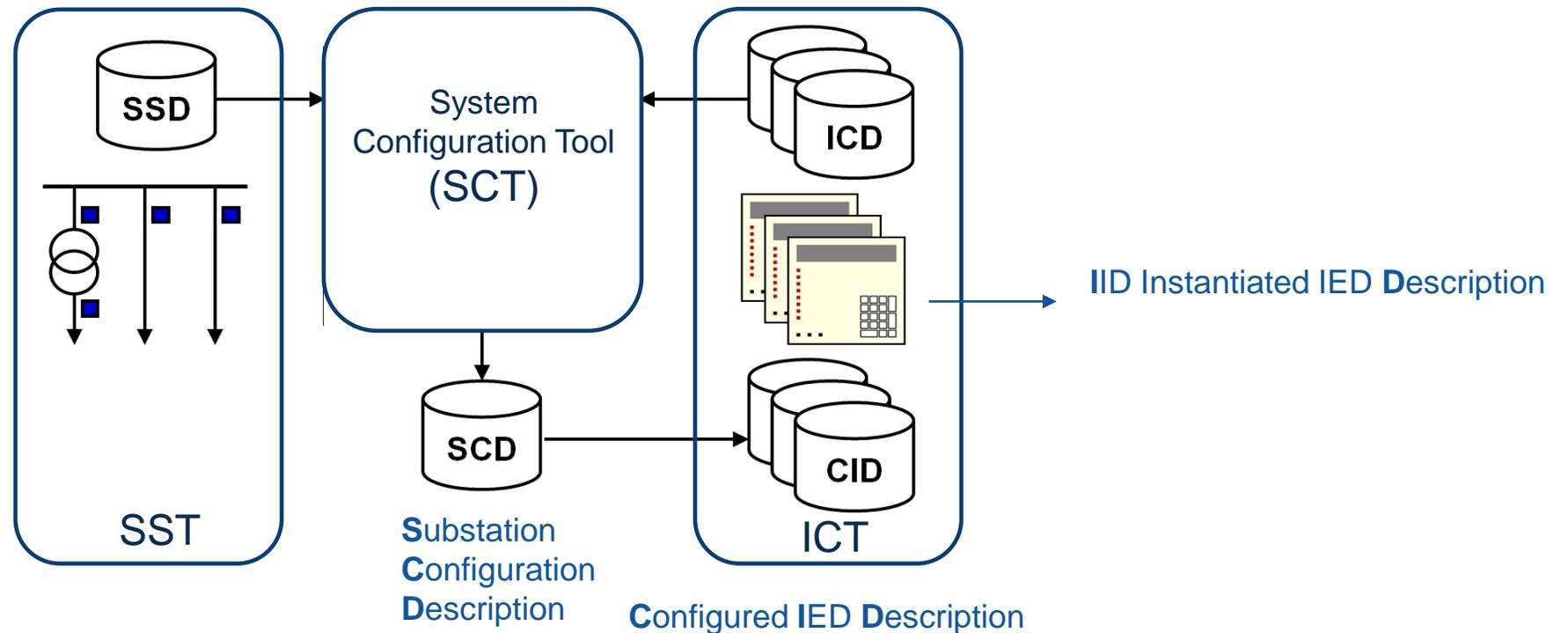


Engineering of IEC 61850 with SCL

- > IEC 61850-6
- > Configuration of overall communication system
- > Interoperability between Engineering Tools

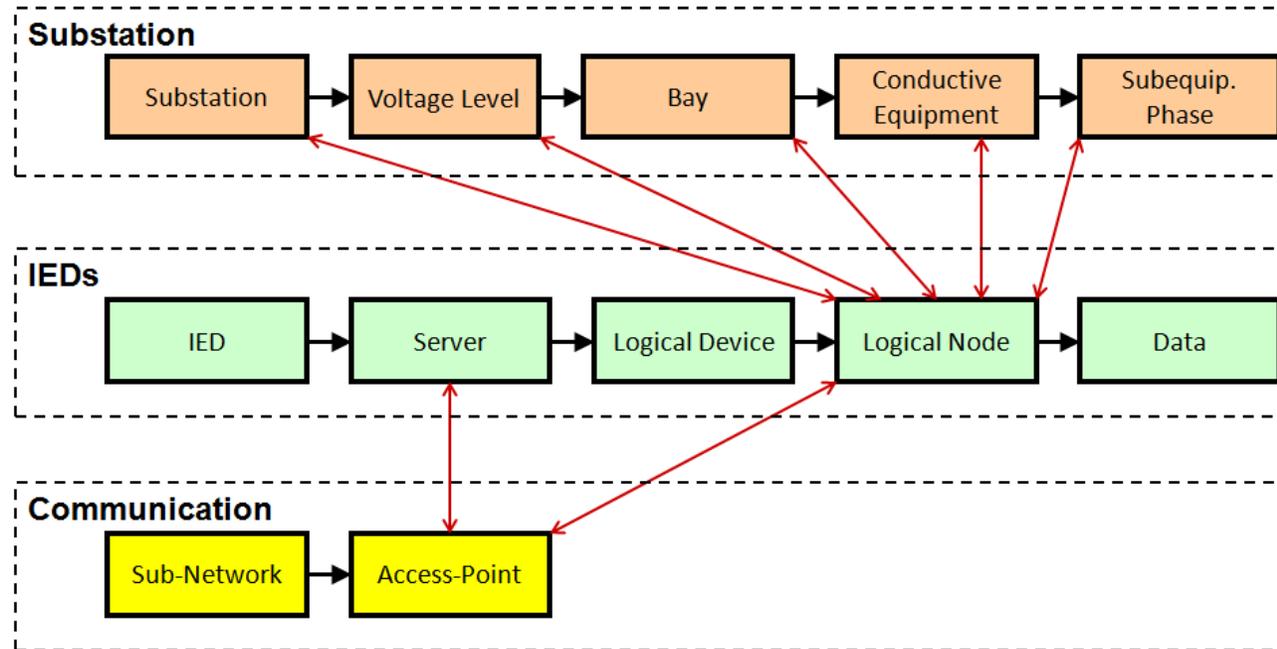
System Specification Description

IED Capability Description



SCL Scope

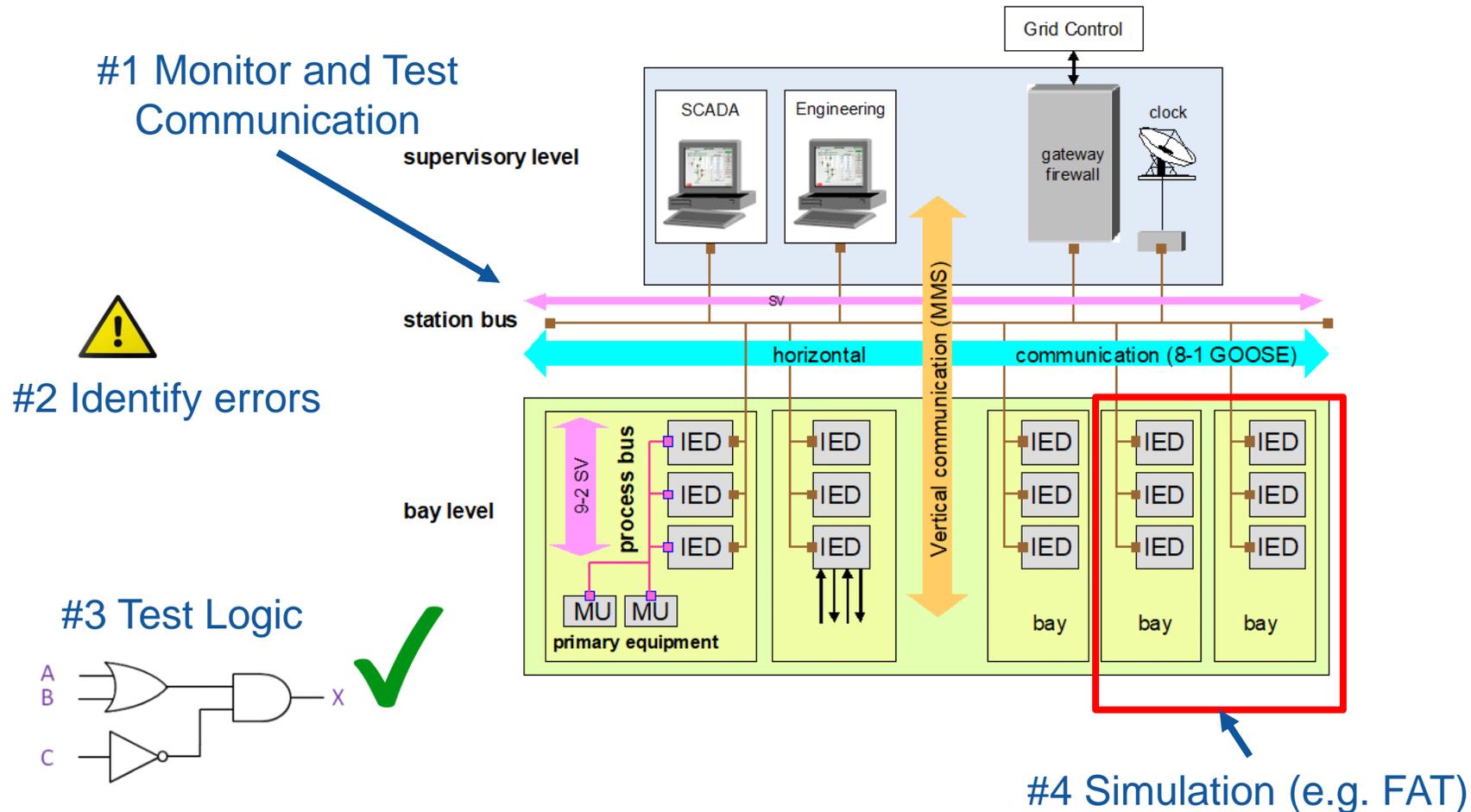
- > SCL uses XML-based files
- > An SCL file contains following information:



- > IEDs: Data Models and Configuration of Reports, GOOSE, SV
- > Correlation between Switchgear and Functions to IED Logical Nodes
- > Communication links between IEDs

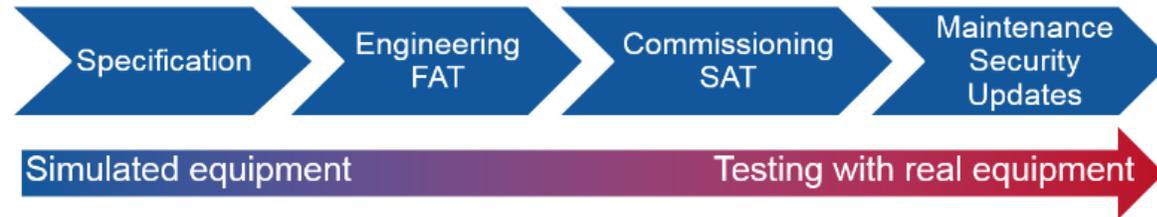
New Test Approach

- > Based on SCL Information
- > Visualize and Test entire Substation Automation System
- > Automated Test Plans

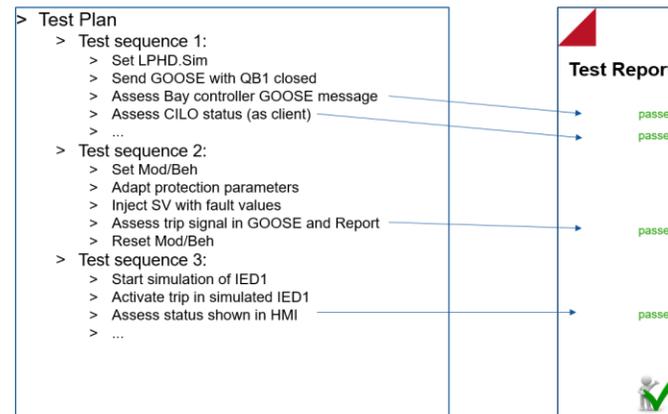


New Test Approach

- > Testing the SAS during its entire Lifecycle



- > Automated Test Plans



Requirements for Efficient Testing:

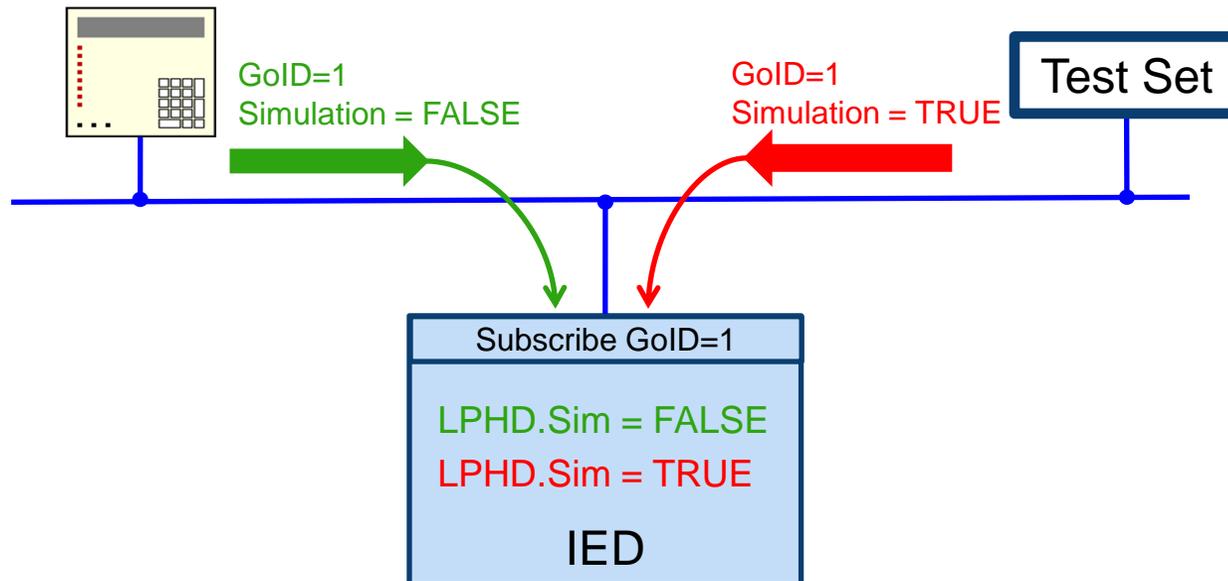
- Optional IED Features
- Quality SCD file!

Test Mode and Simulation Flag

> Test Mode: what are the DUT



> Simulating Messages with Test Set

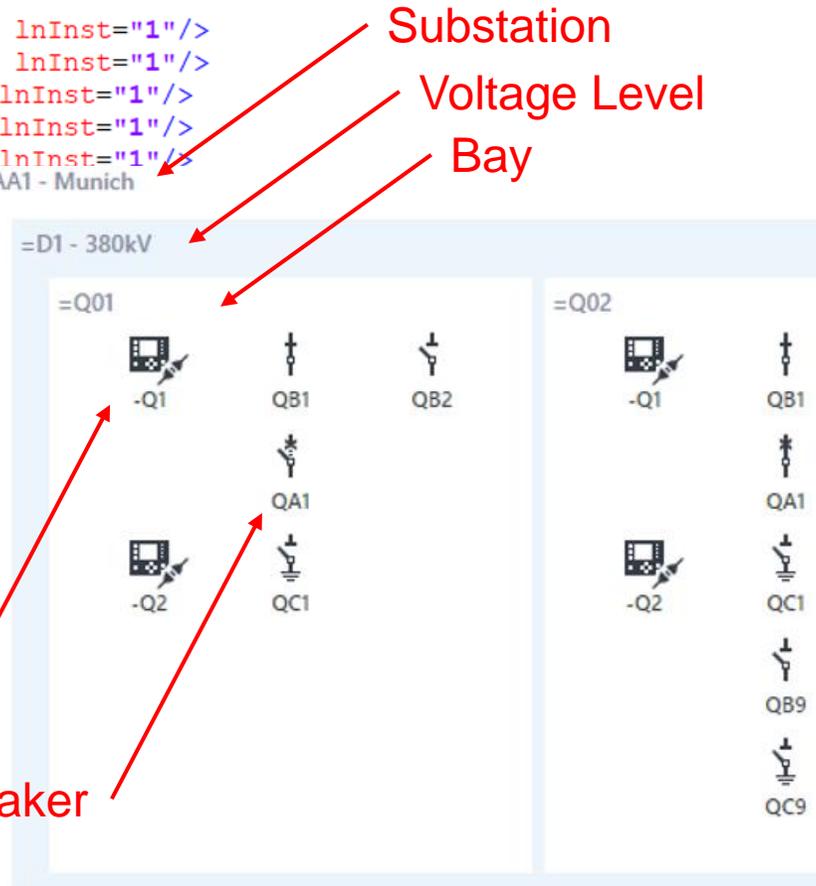


SCD Substation Section

Req.#2

> Substation Topology in SCD

```
<Substation desc="Munich" name="AA1" sxy:x="1" sxy:y="5">  
  <PowerTransformer name="TA1" sxy:y="9" type="PTR">  
  <PowerTransformer name="TA2" sxy:x="15" sxy:y="9" type="PTR">  
  <VoltageLevel name="D1">  
    <Voltage multiplier="k" unit="V">380</Voltage>  
    <Bay desc="TF1" name="Q01" sxy:x="1" sxy:y="2">  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q01F1" lnClass="PDIS" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q01F1" lnClass="PTOC" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q2" ldInst="T3S1S1" lnClass="ATCC" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q2" ldInst="T3T1P1" lnClass="YLTC" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q2" ldInst="T3T1P1" lnClass="YPTR" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q01F1" lnClass="PTRC" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q01F1" lnClass="RBRF" lnInst="1"/>  
      <LNode lnClass="MMXU" lnInst="1"/>  
    <ConductingEquipment name="BC1" sxy:y="4" type="CTR">  
    <ConductingEquipment name="QA1" sxy:y="5" type="CBR">  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q02QA1" lnClass="C" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q02QA1" lnClass="X" lnInst="1"/>  
      <LNode iedName="AA1D1Q01Q1" ldInst="C1Q02QA1" lnClass="C" lnInst="1"/>  
      <Terminal bayName="Q01" cNodeName="L11" name="L11" subst="AA1-Munich" />  
      <Terminal bayName="Q01" cNodeName="L12" name="L12" subst="AA1-Munich" />  
    </ConductingEquipment>  
  </Bay>  
</VoltageLevel>  
</Substation>
```



IED

Breaker

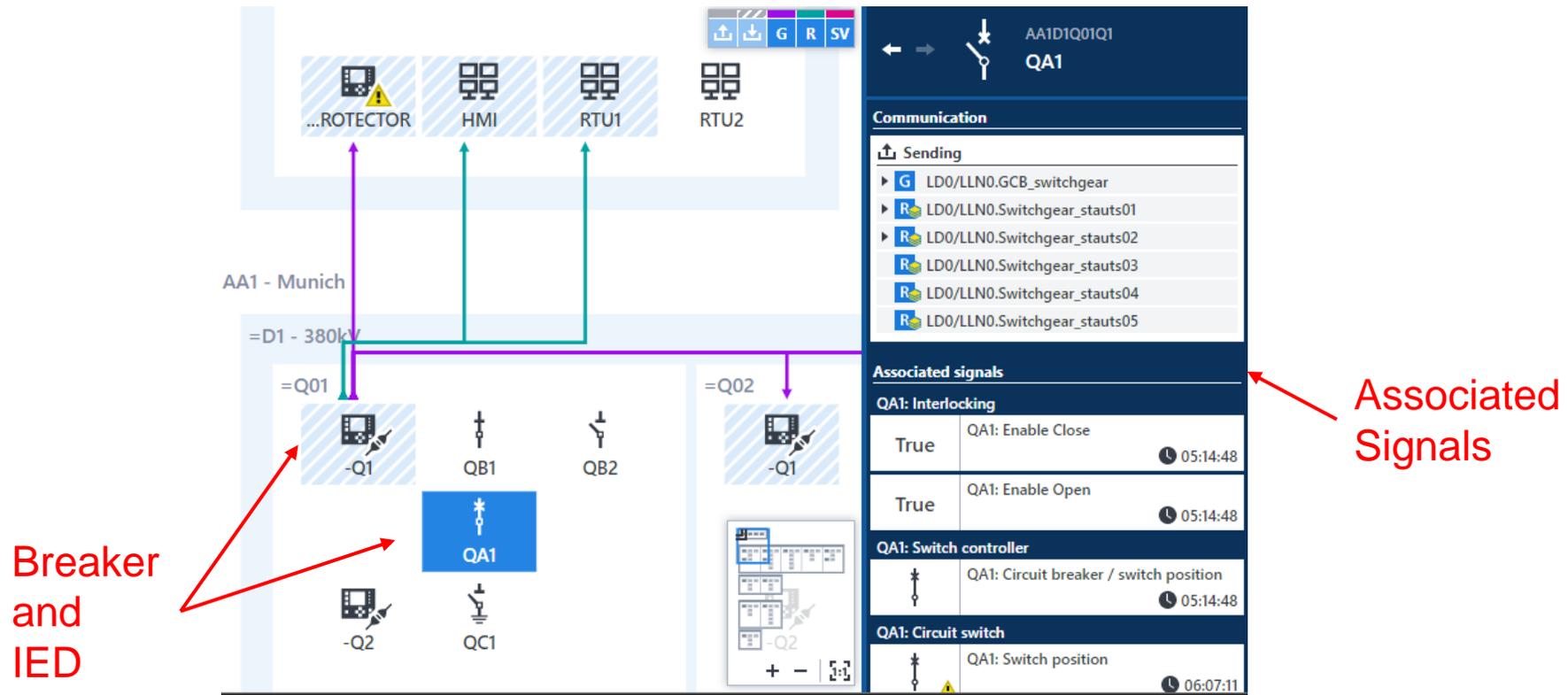
Testing Tool

SCD Substation Section

Req.#2

> Association between Switchgear and LNs

```
<ConductingEquipment name="QA1" sxy:y="5" type="CBR">  
  <LNode iedName="AA1D1Q01Q1" ldInst="C1Q02QA1" lnClass="CILO" lnInst="3"/>  
  <LNode iedName="AA1D1Q01Q1" ldInst="C1Q02QA1" lnClass="XCBR" lnInst="1"/>  
  <LNode iedName="AA1D1Q01Q1" ldInst="C1Q02QA1" lnClass="CSWI" lnInst="3"/>  
  <Terminal bayName="Q01" cNodeName="L11" name="L11" substationName="AA1" vo  
  <Terminal bayName="Q01" cNodeName="L12" name="L12" substationName="AA1" vo  
</ConductingEquipment>
```



- > “desc” attribute of Data Objects should be present in SCD file
- > IEC 61850 allows to hide 61850
- > Instead of Complex Addresses, use signal names from Engineering
- > If unavailable, use smart names from Standard

The screenshot displays a software interface with a tooltip and a data table. The tooltip on the left shows details for the signal 'QA1: Switch position', including its value 'Open', quality 'Invalid' (indicated by a yellow warning triangle), and a timestamp '2019-03-21 06:04:54.595Z' with an accuracy of '≤ 10 ms (T0)'. The main interface shows a table with two rows of data. The first row is for 'QA1: Circuit switch' and the second for 'QA1: Block opening'. Both rows show a value (a switch symbol and 'False' respectively) with a yellow warning triangle, and a timestamp. A mouse cursor is pointing at the text 'QA1: Switch position' in the first row.

QA1: Circuit switch		05:14:48
* ⚡	QA1: Switch position	06:04:54
False	QA1: Block opening	05:14:48

Req.#4

Describing GOOSE connections

- > Subscriptions defined in SCD

```
<GSEControl name="GCB_switchgear" type="GOOSE"
  <IEDName>BB_PROTECTOR</IEDName>
  <IEDName>AA1D1Q02Q1</IEDName>
  <IEDName>AA1D1Q03Q1</IEDName>
  <IEDName>AA1D1Q04Q1</IEDName>
  <IEDName>AA1D1Q05Q1</IEDName>
</GSEControl>
```

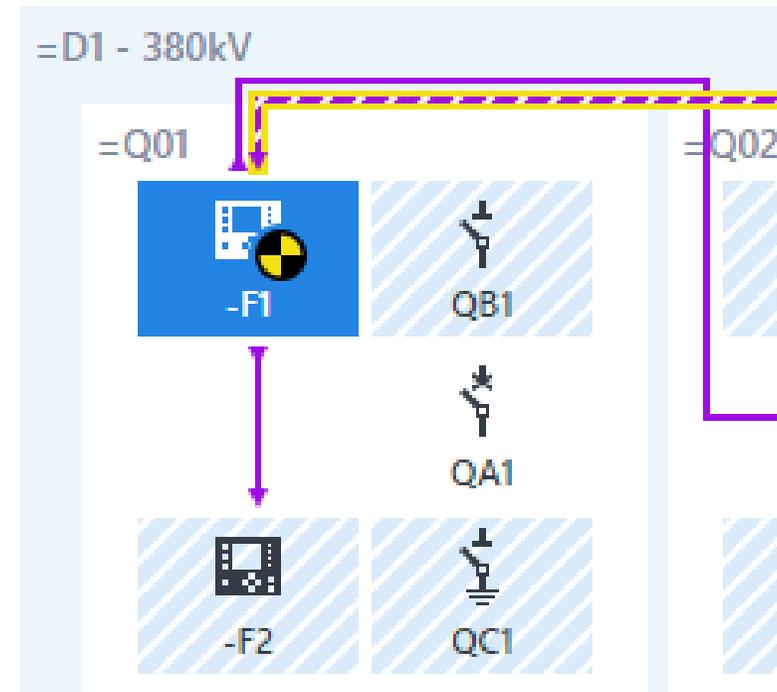
- > Use of LGOS

- > Logical Node for GOOSE Subscription
- > One per Subscription
- > Enable Monitoring of Receive Status

- > Benefit → Check of GOOSE links:

- > Verify Publisher
- > Verify mismatches by comparing traffic with SCD
- > Verify Reception with Subscribers LGOS

AA1 - Niflheim

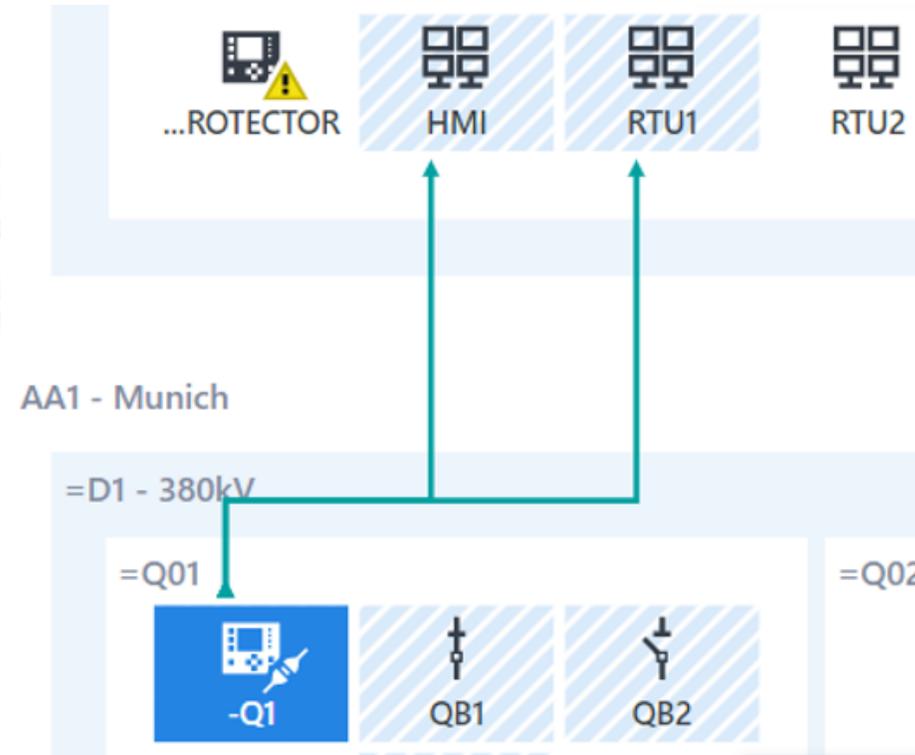


Req.#5

Report Configuration

- > Reports used for SCADA Communication
- > One-to-one connections between IED and Clients
- > Reports can be reserved
 - > "Owner" attribute
 - > Described in SCD

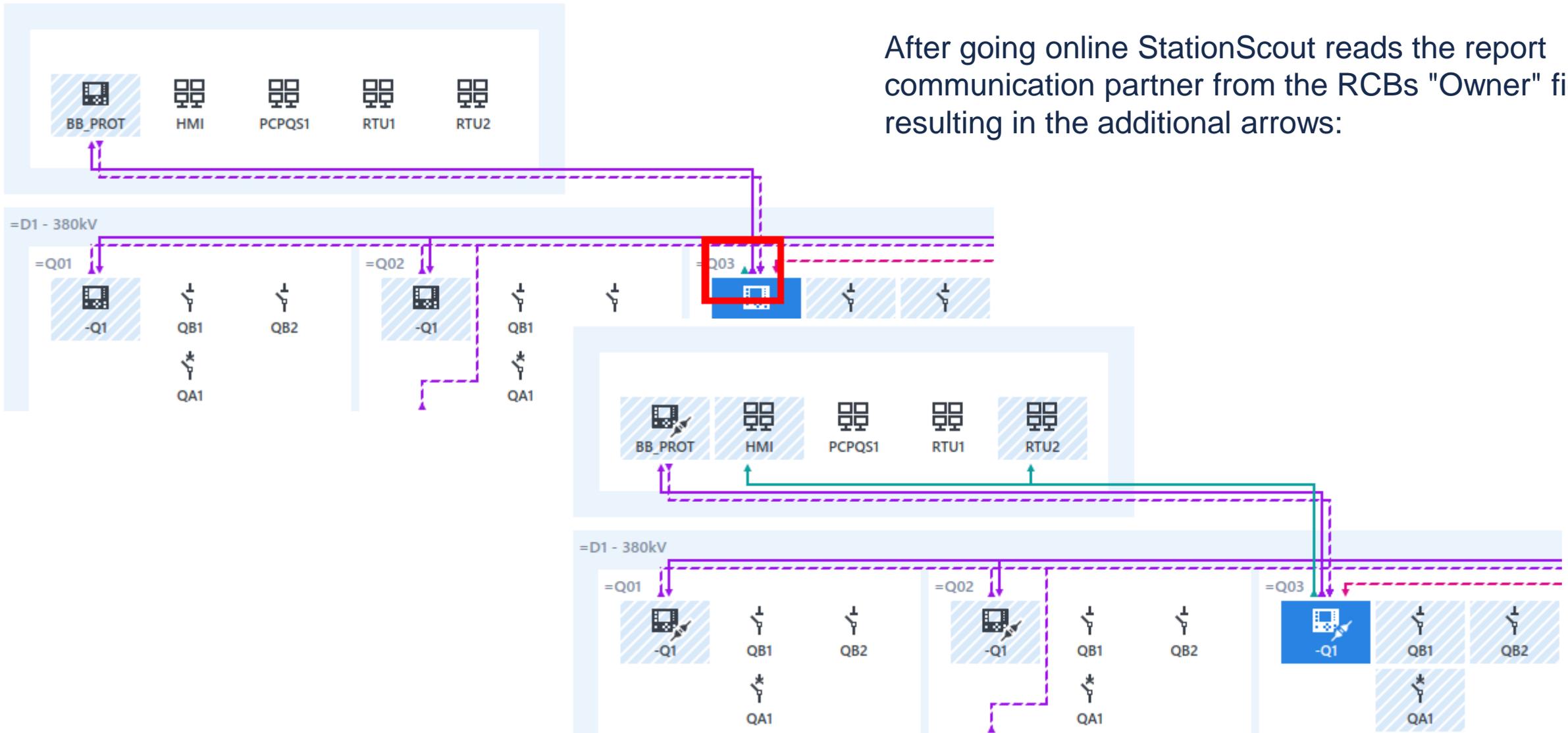
```
<ReportControl name="Measurments" buffered="true" bufTime="100"  
  <TrgOps dchg="true" qchg="true" dupd="true" period="true"  
  <OptFields seqNum="true" timeStamp="true" dataSet="true"  
  <RptEnabled max="5">  
<ClientLN iedName="HMI" ldInst="none" lnInst="1" lnClass="IHMI"  
<ClientLN iedName="RTU1" ldInst="none" lnInst="1" lnClass="ITCI"  
  </RptEnabled>  
</ReportControl>
```



- > Benefit → Check Report links:
 - > Verify "Owner" is the Client defined in the SCD

Dynamic Reports

After going online StationScout reads the report communication partner from the RCBs "Owner" field resulting in the additional arrows:



Dynamic DataSets

AA1D1Q04Q1
Transformer bay Q04

Details

Status: Connection to IED estab...

IP address: 192.168.1.155

Vendor: ACME

Model: PROTEC 400

Simulation

Control

QA1: Circuit breaker

QB2: Circuit switch 1

QC1: Circuit switch 2

QB1: Circuit switch 4

Interlocking

QB2: Interlocking 1 All allowed

QC1: Interlocking 2 All allowed

QB1: Interlocking 3 All allowed

QA1: Interlocking 5 All allowed

```

Open  [icon]  signal_import.txt  Save
/tmp/build_image/output

AA1D1Q04Q1LD0/PTOC1.Op  Time overcurrent - Trip
AA1D1Q04Q1LD0/PTRC1.Str Trip conditioning - Start
AA1D1Q04Q1LD0/PTRC1.Tr  Trip conditioning - Trip
AA1D1Q04Q1LD0/XCBR2.Pos QA1 - Position
AA1D1Q04Q1LD0/XSWI1.Pos QB2 - Position
AA1D1Q04Q1LD0/XSWI2.Pos QC1 - Position
AA1D1Q04Q1LD0/XSWI4.Pos QB1 - Position
AA1D1Q04Q1LD0/XSWI5.Pos Reference does not exist in IED
AA1D1Q04Q1LD0/ATCC1.CtlV
AA1D1Q04Q1LD0/ATCC1.ParOp
AA1D1Q04Q1LD0/ATCTR4.AmpSv
AA1D1Q04Q1LD0/BTCTR1.AmpSv
AA1D1Q04Q1LD0/CTCTR2.AmpSv
AA1D1Q04Q1LD0/MMXU1.A
AA1D1Q04Q1LD0/MMXU1.Hz
AA1D1Q04Q1LD0/MMXU1.PPV
AA1D1Q04Q1LD0/MMXU1.PPV
AA1D1Q04Q1LD0/MMXU1.PPV
AA1D1Q04Q1LD0/MMXU1.PhV
AA1D1Q04Q1LD0/MMXU1.TotW
AA1D1Q04Q1LD0/MMXU1.W
AA1D1Q04Q1LD0/SPTR1.CGAlm
AA1D1Q04Q1LD0/SPTR1.HPTmpClc
AA1D1Q04Q1LD0/YLTC1.EndPosL
AA1D1Q04Q1LD0/YLTC1.EndPosR
AA1D1Q04Q1LD0/YLTC1.OpCnt
AA1D1Q04Q1LD0/YLTC1.TapChg
AA1D1Q04Q1LD0/YPTR1.OpTmh
  
```

Dynamic DataSets

Signal Name Import

Copy or drag two columns (e.g. from Excel) to the table. One column must contain paths in MMS or IEC 61850 format and the other one the corresponding signal names.

MMS IEC 61850 references	Name	Comment
+ AA1D1Q04Q1LD0/PTOC1.Op.general	Time overcurrent - Trip - general	
+ AA1D1Q04Q1LD0/PTOC1.Op.phsA	Time overcurrent - Trip - phsA	
+ AA1D1Q04Q1LD0/PTRC1.Str.general	Trip conditioning - Start - general	
+ AA1D1Q04Q1LD0/PTRC1.Str.dirGeneral	Trip conditioning - Start - dirGeneral	
+ AA1D1Q04Q1LD0/PTRC1.Tr.general	Trip conditioning - Trip - general	
+ AA1D1Q04Q1LD0/PTRC1.Tr.phsA	Trip conditioning - Trip - phsA	
AA1D1Q04Q1LD0/XCBR2.Pos.stVal	QA1 - Position	Switch position
AA1D1Q04Q1LD0/XSWI1.Pos.stVal	QB2 - Position	Switch position 1
AA1D1Q04Q1LD0/XSWI2.Pos.stVal	QC1 - Position	Switch position 2
AA1D1Q04Q1LD0/XSWI4.Pos.stVal	QB1 - Position	Switch position 4
AA1D1Q04Q1LD0/XSWI5.Pos	Reference does not exist in IED	
AA1D1Q04Q1LD0/ATCC1.Cuv.mag		
+ AA1D1Q04Q1LD0/ATCC1.ParOp.stVal		
+ AA1D1Q04Q1LD0/BTCTR1.AmpSv.instMag		
+ AA1D1Q04Q1LD0/CTCTR2.AmpSv.instMag		

4 updated signals
+ 32 new signals
x 1 invalid signal
36 signals will be imported

Delete selected signals

Import Cancel

Receiving

New signals with names

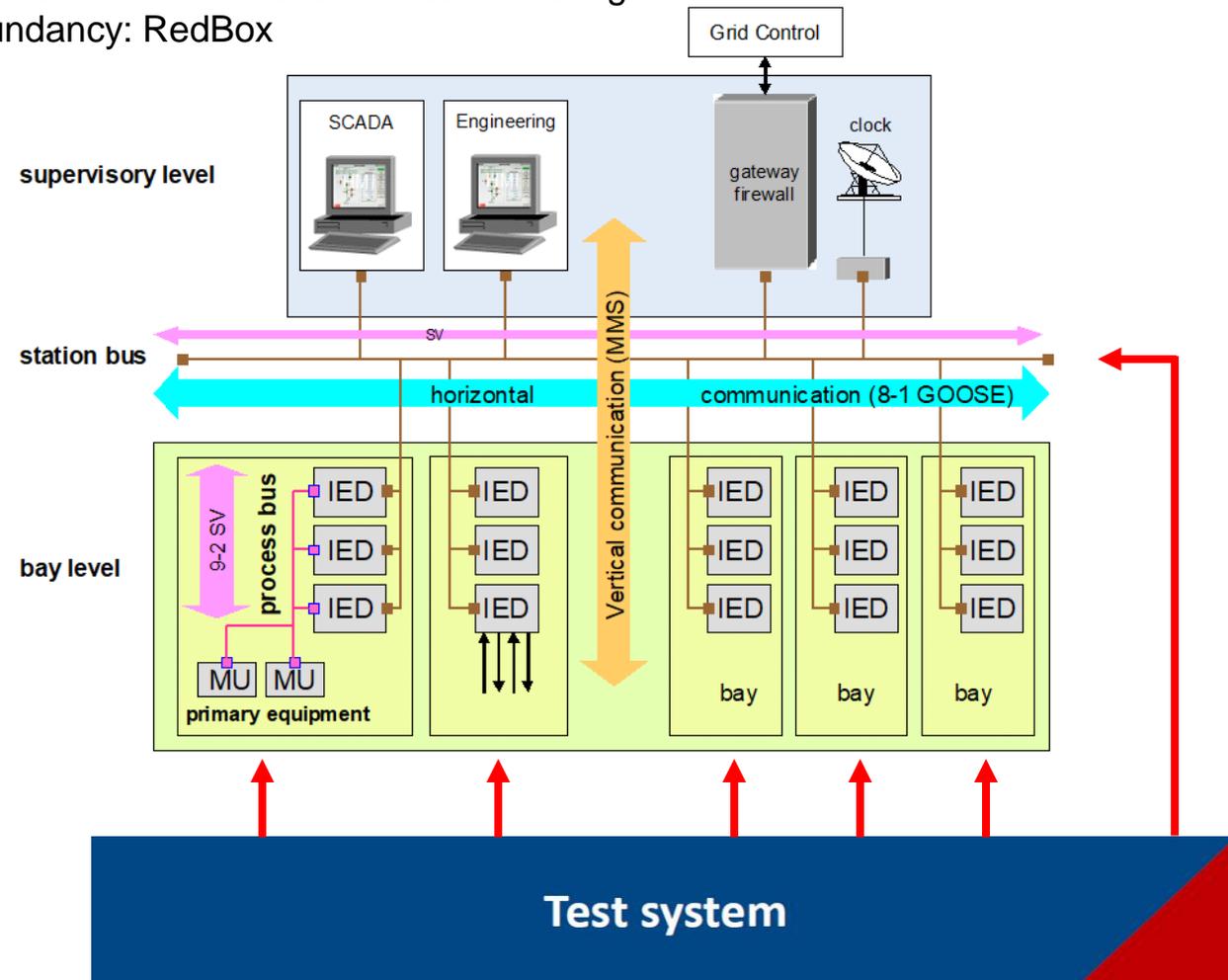
Rename existing signals

Invalid reference

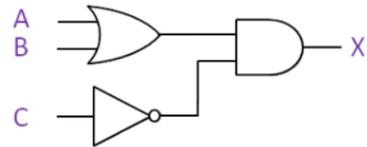
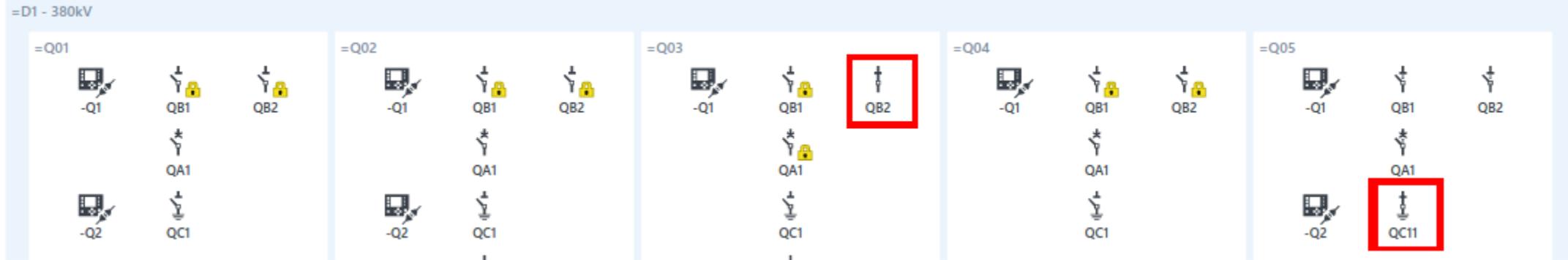
New signals with default names

Network Design Considerations

- > Testing Requirements should be considered for Network Design
- > Clear Access Points for Testing considering:
 - > Topology: Station Bus and Process Bus
 - > Traffic Control: VLAN and Multicast Filtering
 - > Redundancy: RedBox



Example: Testing Interlocking Logics



Interlockings

> CILO LN shows interlocking logic result for each switch

▼ Test case Q01-1

Simulation

QB1:  QB2:  QA1: 

Assessments

QB1-CILO: close-locked

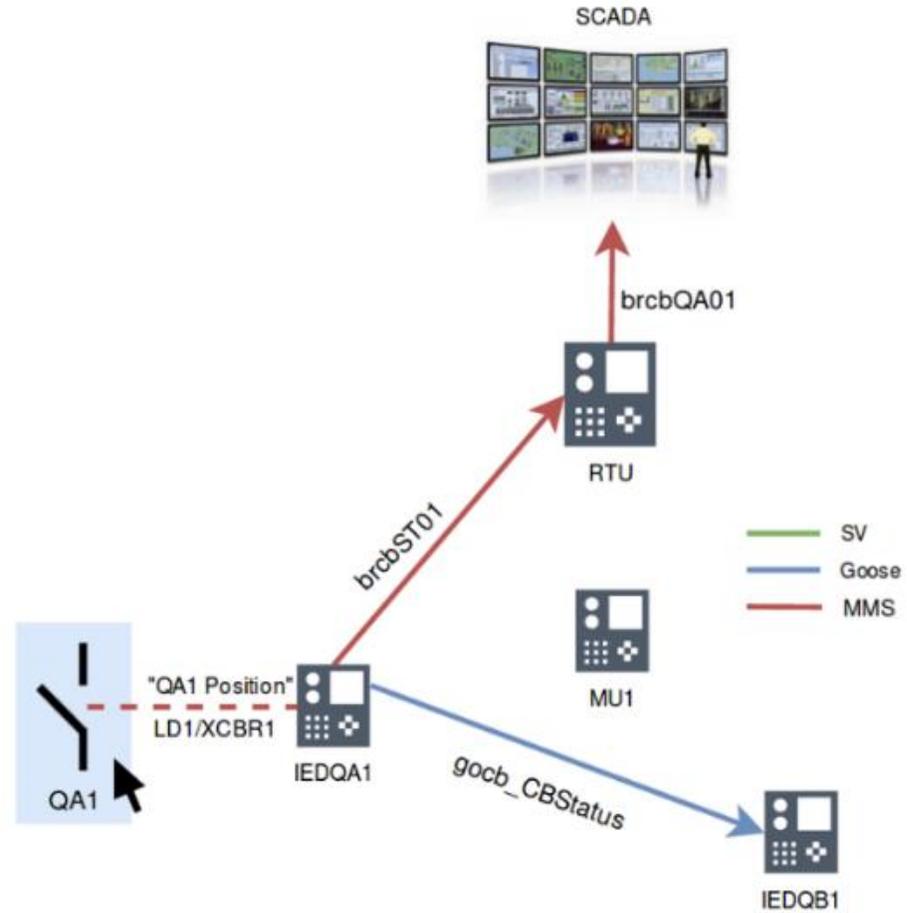
QB2-CILO: open-locked

QA1-CILO: unlocked

▶ Test case Q01-2

Example: Troubleshooting

> Tracing Signals through the SAS



Example: Re-testing after Security Updates

Test Report

GOOSE	passed
Reporting	passed
Test modes	passed
Interlocking	passed



Before firmware update



Test Report

GOOSE	passed
Reporting	passed
Test modes	passed
Interlocking	passed



After firmware update

Conclusion

- > SCL is a very powerful aspect of IEC 61850
- > Benefits go beyond engineering:
 - > Testing / Monitoring
 - > Cybersecurity
 - > Documentation
- > Save Time and Increase Efficiency Using what SCL Offers
- > Challenges:
 - > Some features are Optional
 - > Lack of Tools
- > Requirements to be considered during System Design and Engineering
- > Enable New Test Methods for entire SAS Lifecycle
 - > Automated Test Plans
 - > Simulation during Design and FAT Phase
 - > Re-test after Security Firmware/Patches Updates
- > Enable Functional Security Monitoring of the SAS

Thank you!

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