The Integrated Application

IOP 2019

Christoph Brunner
Switzerland

it4power

History of the Integrated Application

- Since 2011 we did an IOP every second year
- Initially testing individual elements of the standard with pair of vendors
  - GOOSE
  - Client / server
  - SCL
- 2015, with 10 year since publication, the basic communication had reached good level of interoperability
- Issues remained with regard to engineering and modeling
- Idea was created, to build all together a real application instead of testing between pairs of vendors

Challenges of an integrated application

- How to produce reasonable test results?
- How to fit the variety of devices?
- How to fill the gaps – the chance that you get exactly the devices you need is low
- How to deal with quality of ICD files? - All the challenges of interoperability related to engineering and data modeling have to be solved before the IOP

→Have realistic expectations and deal with them

→Coordination is required

What we learned from 2017

- 2017, we designed the protection and control of a multi-vendor substation within 2 days
  - But that was during the IOP itself
  - We never tested the application
- What we changed
  - We insisted to get the icd files early, checked them with various checkers and sent them back – quality of icd files has now improved
  - We could allocated devices to the application earlier
  - We allocated three days of setup – build the network, discuss the IED usage with the vendors, load the scd file in IED tools and configure the IEDs

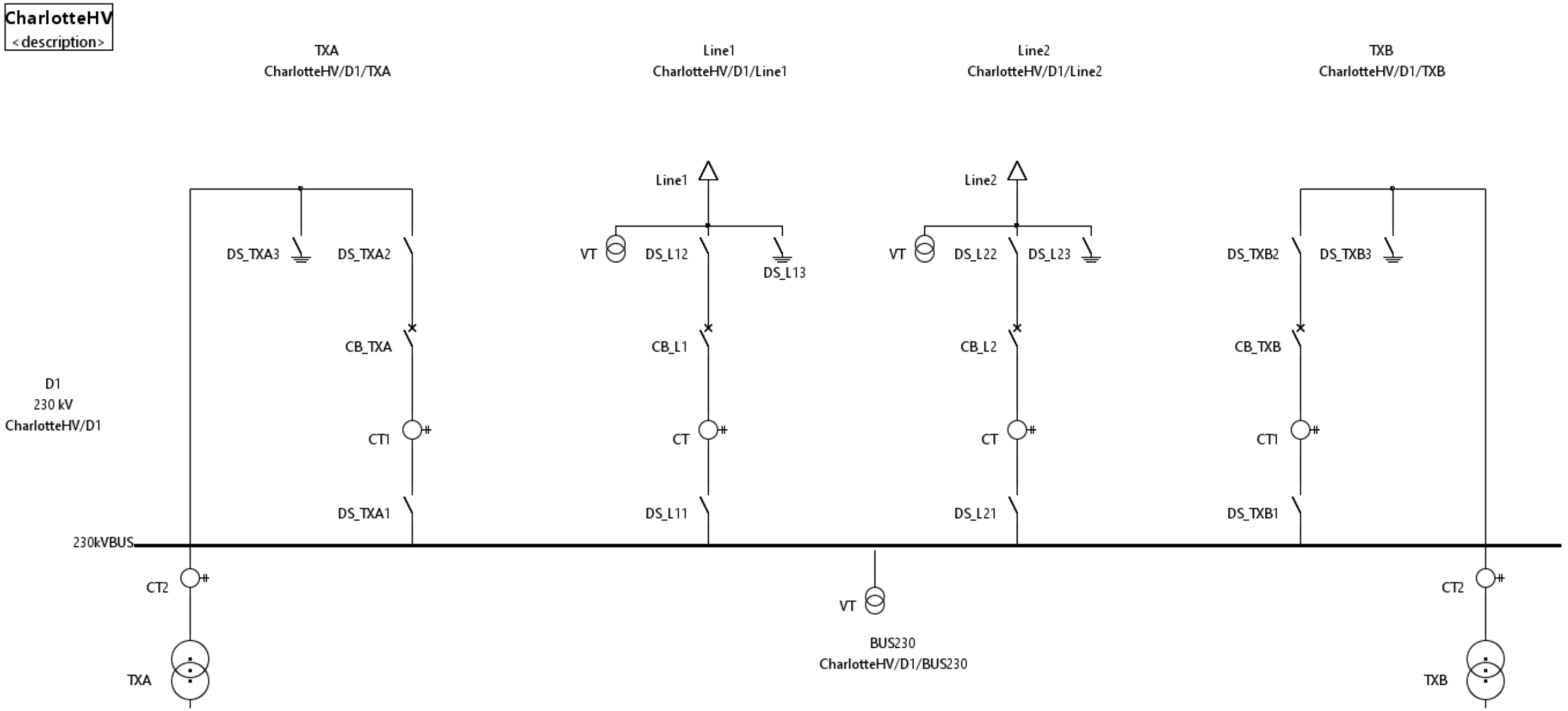
What we learned from 2017

- We need to have a test plan – the test specifications are not enough
  - For the preparation – the integrated application should be configured by Sunday night – ready to start testing on Monday
  - For the tests themselves – when are we doing tests of the application and when are we doing individual tests between pair of vendors
  - As we are building an integrated application, we shall as well test that – this requires coordination

The application as a playground for engineers

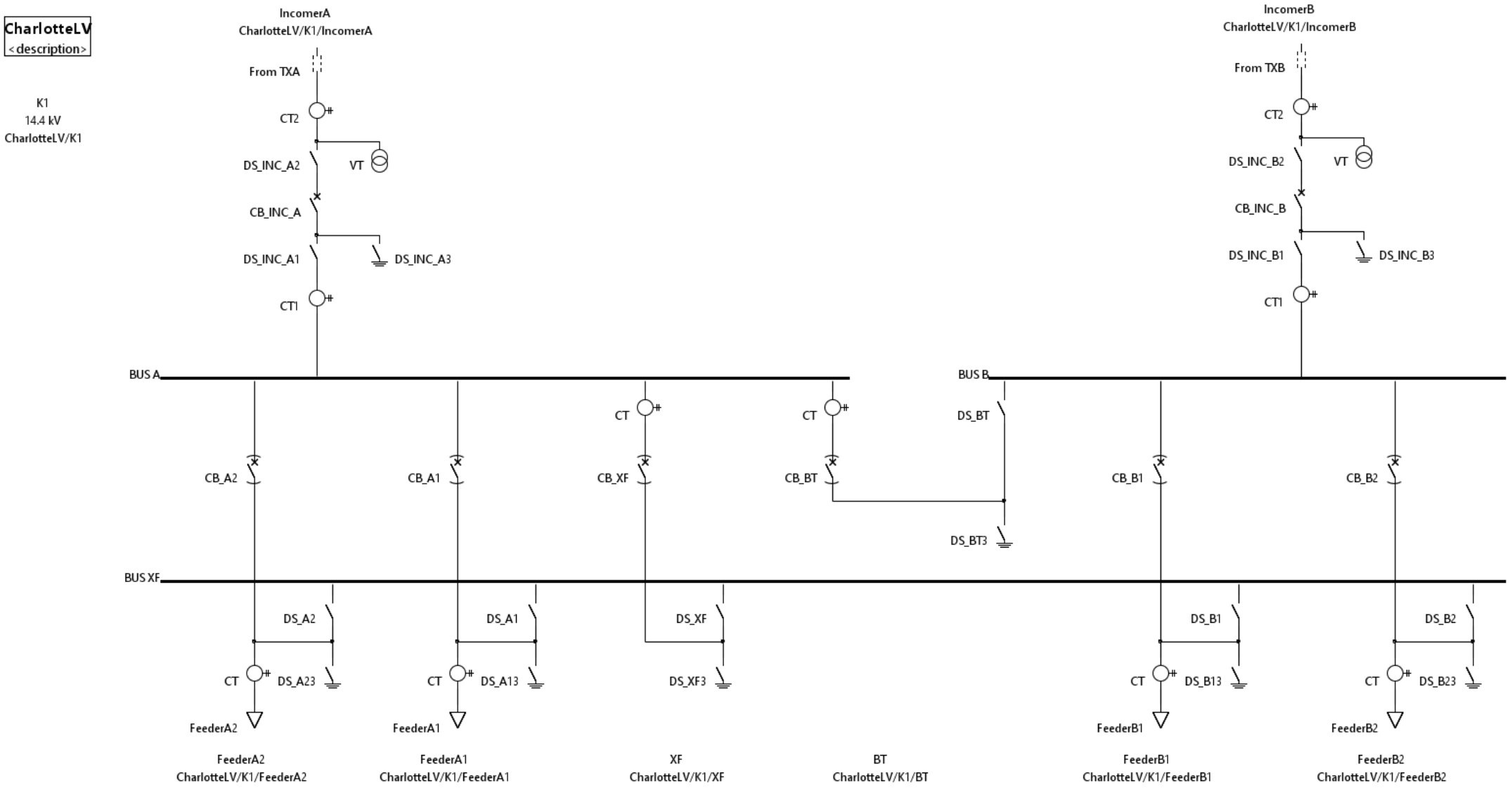
- What are the requirements for an application to be used?
  - Shall be realistic
  - Shall be scalable – depending on the number of participants
  - Shall allow for many GOOSE messages – ideally every device can publish and subscribe GOOSE messages
  - Shall have enough room for merging units
  - Shall be simple from the perspective of simulation of process
  - Shall be dividable in smaller segments to support individual tests
- Application is based on substation from Entergy
  - HV part with to feeders and two transformers
  - LV part with 2 bus sections connected to the two transformers, multiple feeders, a transfer bus and a bus tie

The HV part



it4power

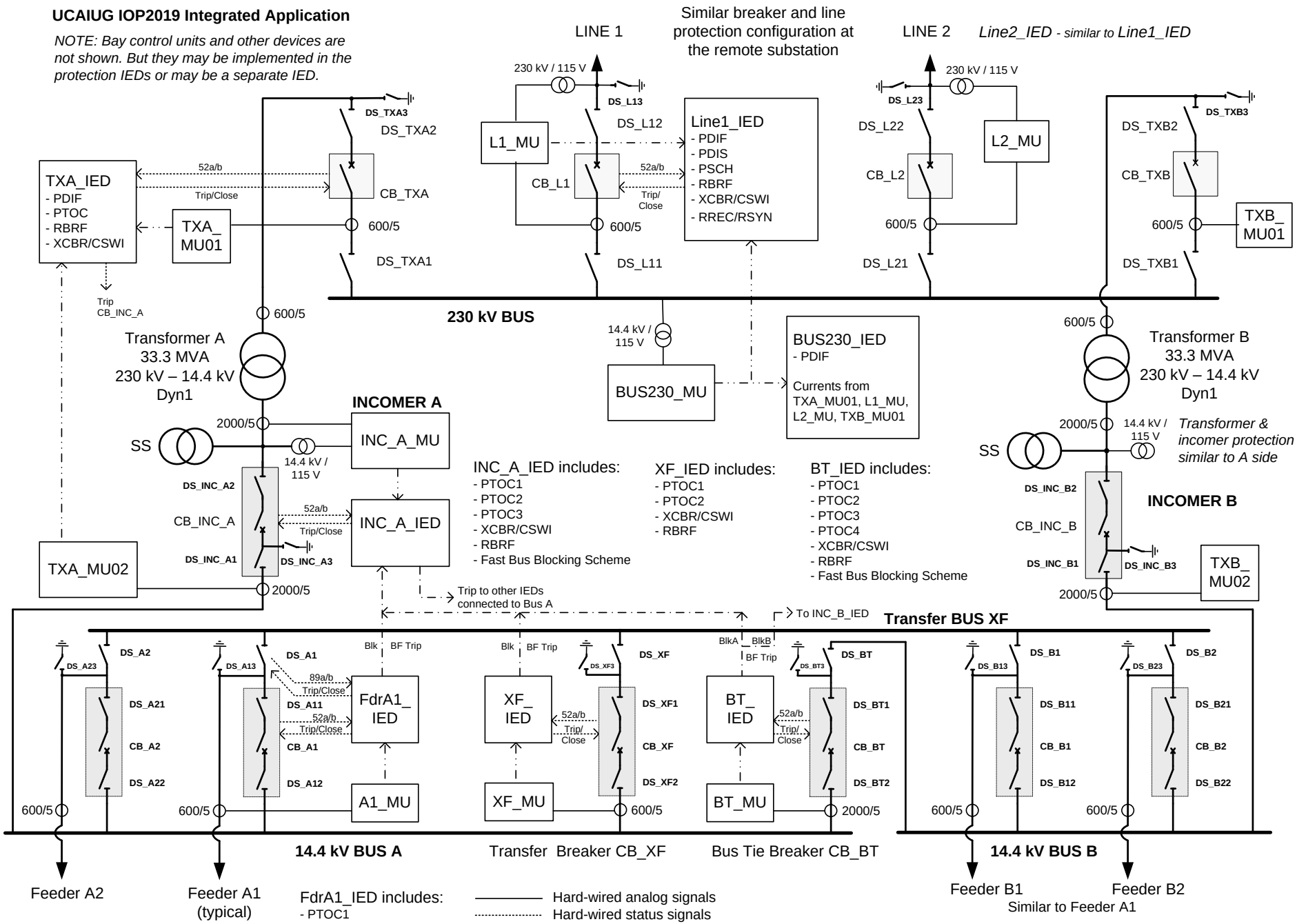
The LV part



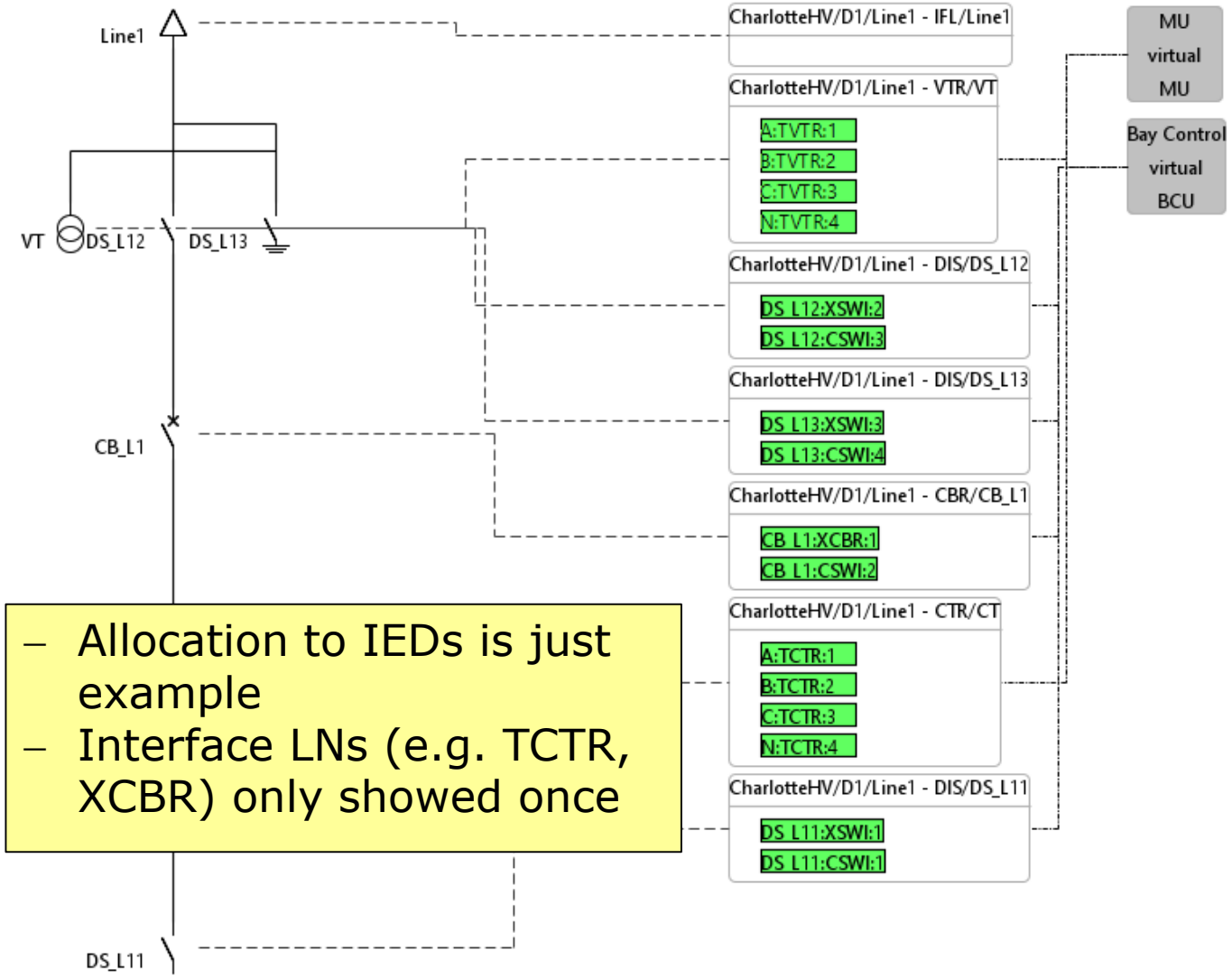
it4power

Design steps (1) – Specification

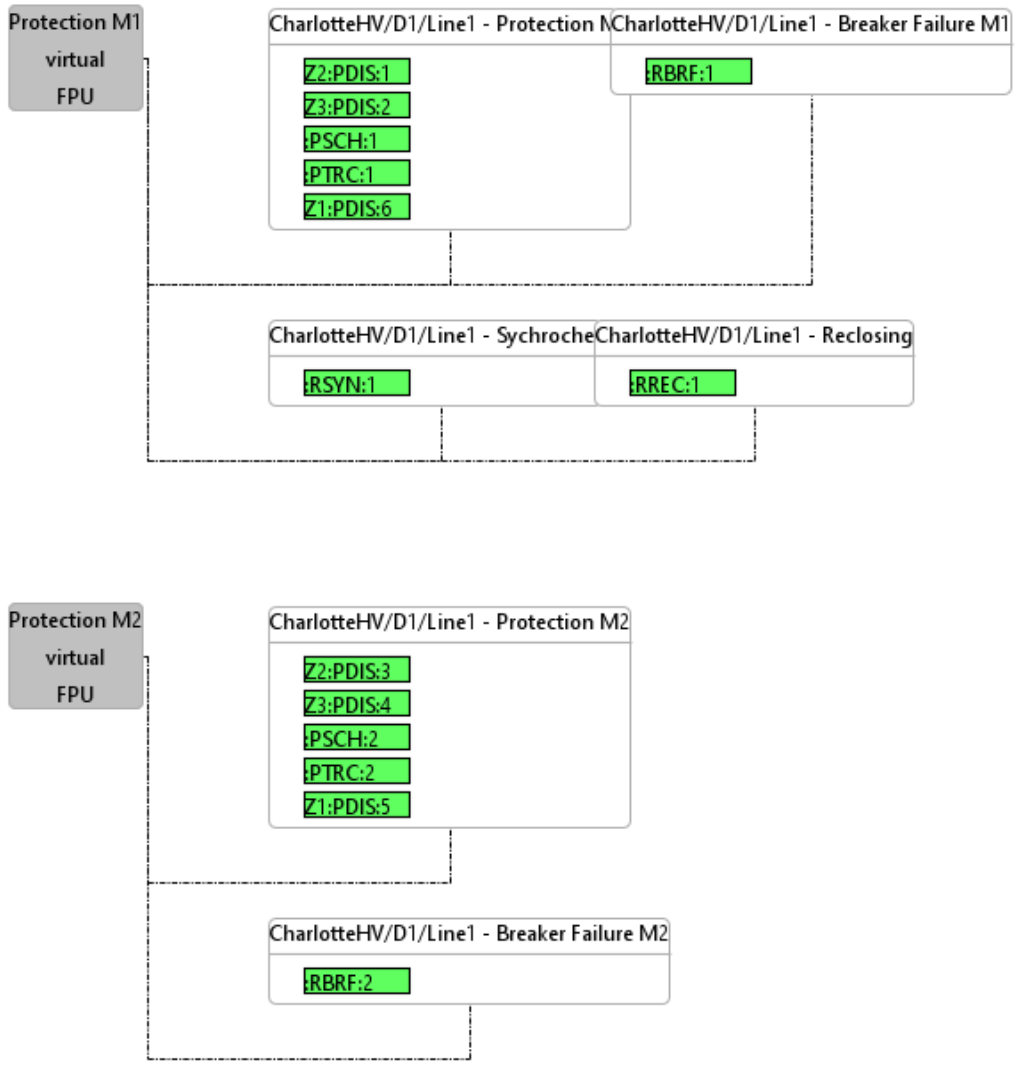
- Identify
  - Required functions
  - Possible allocation to IEDs
  - Interactions between functions


UCAIUG IOP2019 Integrated Application
NOTE: Bay control units and other devices are not shown. But they may be implemented in the protection IEDs or may be a separate IED.
LINE 1
Similar breaker and line protection configuration at the remote substation
LINE 2
Line2_IED - similar to Line1_IED
230 kV / 115 V
DS_L13
DS_L12
L1_MU
Line1_IED
- PDIF
- PDIS
- PSCH
- RBRF
- XCBR/CSWI
- RREC/RSYN
CB_L1
52a/b
Trip/ Close
600/5
DS_L11
DS_L23
DS_L22
L2_MU
CB_L2
DS_L21
DS_TXA3
DS_TXA2
TXA_IED
- PDIF
- PTOC
- RBRF
- XCBR/CSWI
52a/b
Trip/Close
CB_TXA
TXA_ MU01
600/5
DS_TXA1
Trip CB_INC_A
230 kV BUS
DS_TXB3
DS_TXB2
CB_TXB
TXB_ MU01
DS_TXB1
600/5
Transformer A
33.3 MVA
230 kV – 14.4 kV
Dyn1
14.4 kV / 115 V
BUS230_MU
BUS230_IED
- PDIF
Currents from TXA_MU01, L1_MU, L2_MU, TXB_MU01
Transformer B
33.3 MVA
230 kV – 14.4 kV
Dyn1
INCOMER A
2000/5
SS
INC_A_MU
14.4 kV / 115 V
DS_INC_A2
CB_INC_A
DS_INC_A1
DS_INC_A3
INC_A_IED
52a/b
Trip/Close
TXA_MU02
2000/5
INC_A_IED includes:
- PTOC1
- PTOC2
- PTOC3
- XCBR/CSWI
- RBRF
- Fast Bus Blocking Scheme
XF_IED includes:
- PTOC1
- PTOC2
- XCBR/CSWI
- RBRF
BT_IED includes:
- PTOC1
- PTOC2
- PTOC3
- PTOC4
- XCBR/CSWI
- RBRF
- Fast Bus Blocking Scheme
Transformer & incomer protection similar to A side
INCOMER B
DS_INC_B2
CB_INC_B
DS_INC_B1
DS_INC_B3
TXB_ MU02
Trip to other IEDs connected to Bus A
To INC_B_IED
Transfer BUS XF
DS_A23
DS_A2
DS_A21
CB_A2
DS_A22
DS_A13
DS_A1
89a/b
Trip/Close
DS_A11
CB_A1
DS_A12
FdrA1_ IED
A1_MU
Blk
BF Trip
XF_ IED
XF_MU
DS_XF3
DS_XF
DS_XF1
CB_XF
DS_XF2
BlkA
BlkB
BT_ IED
BT_MU
DS_BT3
DS_BT
DS_BT1
CB_BT
DS_BT2
DS_B13
DS_B1
DS_B11
CB_B1
DS_B12
DS_B23
DS_B2
DS_B21
CB_B2
DS_B22
600/5
2000/5
14.4 kV BUS A
Transfer Breaker CB_XF
Bus Tie Breaker CB_BT
14.4 kV BUS B
Feeder A2
Feeder A1 (typical)
Feeder B1
Feeder B2
Similar to Feeder A1
FdrA1_IED includes:
- PTOC1
- PTOC2
- XCBR/CSWI
- XSWI/CSWI
- RBRF
Hard-wired analog signals
Hard-wired status signals
GOOSE signals
Sampled values
Note: The communication network for the GOOSE and SV messages is not shown
NOTES for Zone A:
- Edition 2
- More feeders may be connected
NOTES for Zone B (B xfmr to B feeders):
- Edition 1
- More feeders may be connected

Function Specification – Line 1



- Allocation to IEDs is just example
- Interface LNs (e.g. TCTR, XCBR) only showed once

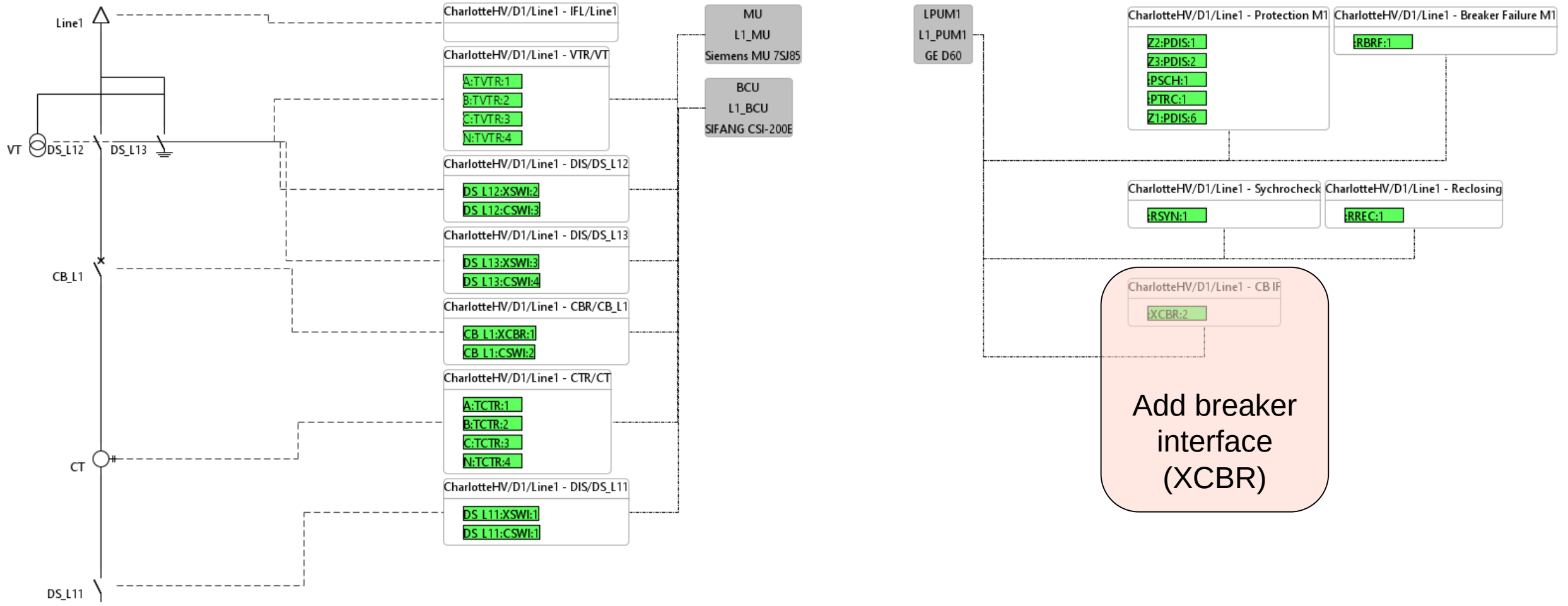


it4power

Design steps (2) – Device allocation

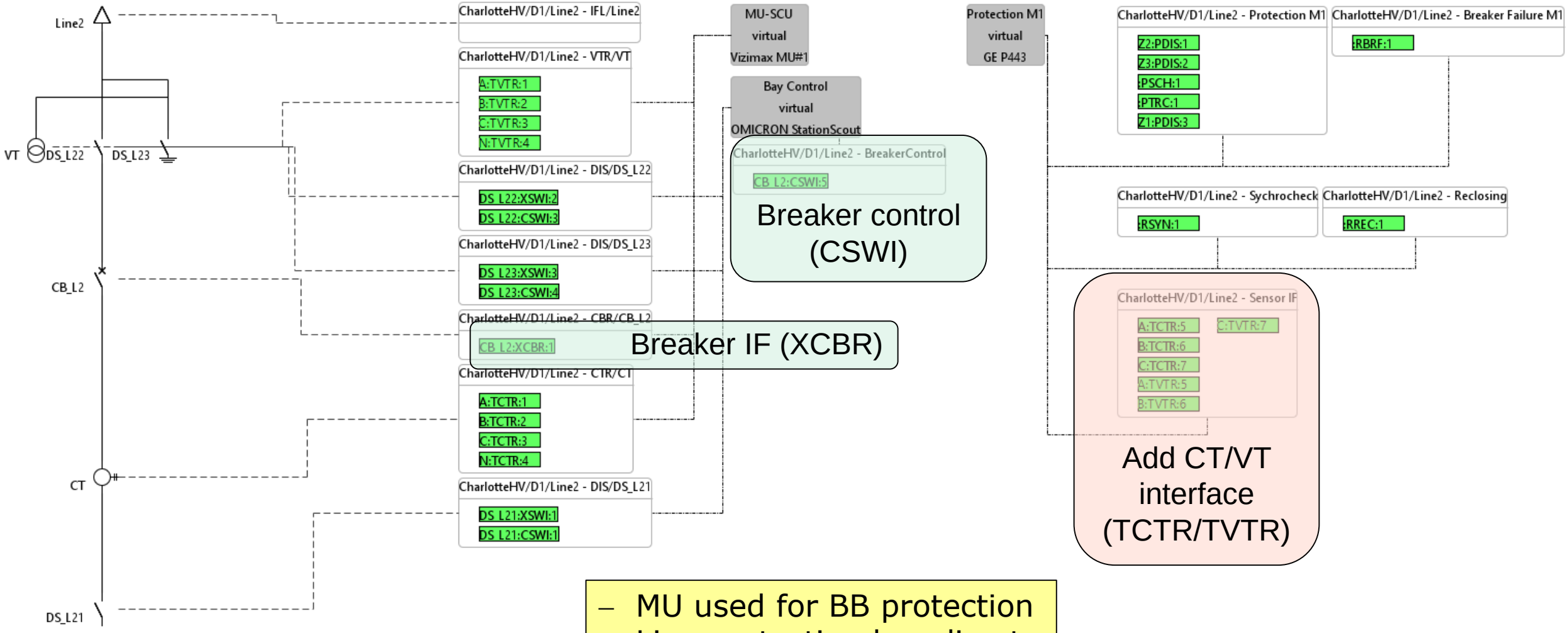
- We have all variations
  - No process bus, where protection devices are wired to the CT/VT and the circuit breakers
  - Merging units that supply sampled values
  - SCUs (Switchgear control units) that interface to the breakers
- GAPs are filled with simulation equipment
  - Simulation of communication
  - Functional simulation within technical limits

Variations – MU but direct trip from PU



it4power

Variations – PU with no SV interface but SCU



- MU used for BB protection
- Line protection has direct interface to TCTR/TVTR

it4power

Interaction between functions

Sending Device	Signal	L1 BCU	L1 PU-M1	L2 MU-SCU	L2 BCU	L2 PU-M2	TXA MU01-SCU	TXA BCU	TXA PU-M1	TXA PU-M3	TXB MU01-BCU	TXB PU-M1	TXB PU-M2	TXB PU-M3	BUS230 PU		IncA PU-BCU	IncB BCU	IncB PU	BT PU-BCU		Substation 2	
Bay L1																							
MU	TCTR.AmpSv TVTR.VolSv	x	x												x								BCU may subscribe for MMXU
BCU	DIS_L11XSWI.Pos														x								
PU-M1	RBRF.OpEx			x			x				x											x	
	RREC.OpCls	x																					
	PSCH.Op																					x	
	RSYN.Rel	x																					
Bay L2																							
MU-SCU	TCTR.AmpSv TVTR.VolSv				x										x								BCU may subscribe for MMXU
	XCBR.Pos				x	x									x								
BCU	CSWI.OpOpn CSWI.OpCls CSWI.SelOpn CSWI.SelCls			x																			
	DIS_L21XSWI.Pos														x								
PU-M1	RBRF.OpEx	x					x				x											x	
	PTRC.Tr			x																			
	RREC.OpCls			x																			
	PSCH.Op																					x	
	RSYN.Rel				x																		

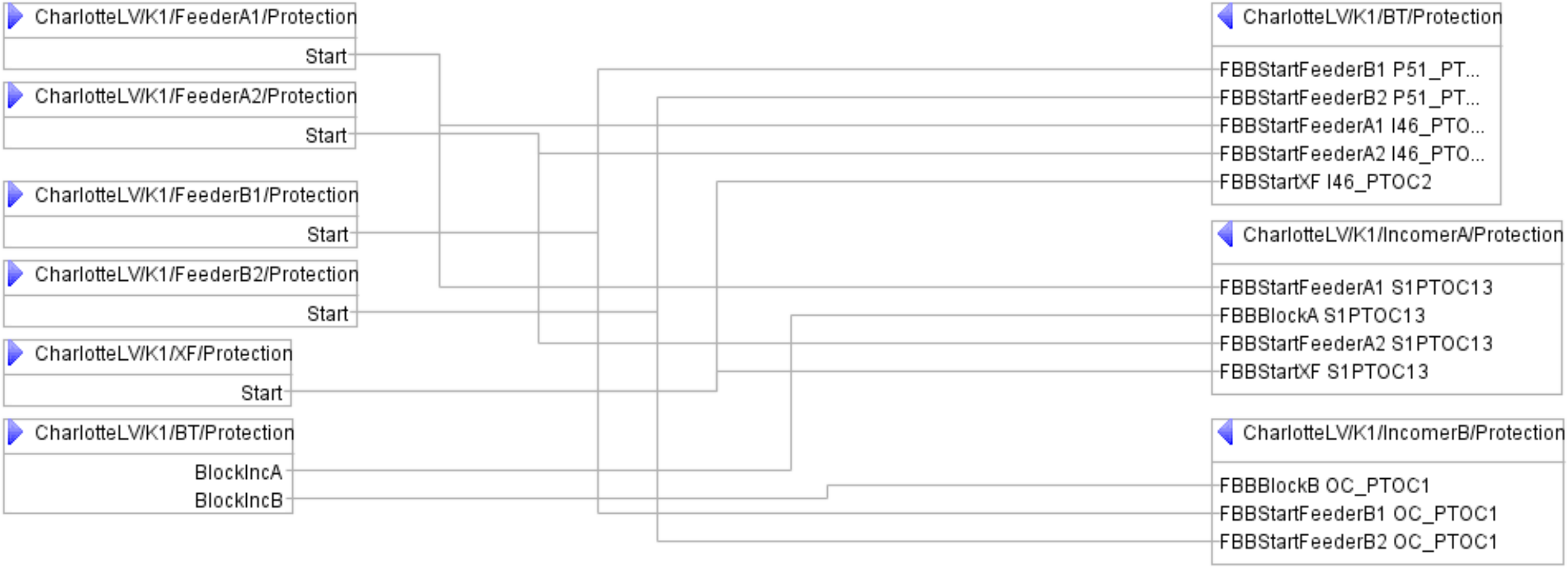
Design steps – Communication network

- Decided to have Station bus and sampled values on a separate process bus
  - Protection devices using sampled values connect to both
- Segregation with VLANs
- IOP is particular, as we have devices that do HSR, others that do PRP
  - We have a PRP process bus and an HSR process bus – each of them with own VLAN ID
  - In limited cases, SV have to go from one to the other – this uses a dedicated VLAN ID

Design steps – SCL design

- Load icd files and create an instance
- Identify which logical nodes are to be used for what function – create mapping based on that
- Create GOOSE / SV messaging
- Define reporting
  - Typically in a IOP, we have more clients than reports are supported by the IEDs

Implementation fast bus blocking scheme



it4power

Design steps – define settings for the functions

- Line parameters and related settings
- Timers for protection functions and breaker failure
- Recloser details

Design steps – plan for simulation of process

- Analog values need to be injected to MUs and PUs not supporting SV
  - Use traditional protection equipment
- Breakers and switches need to be simulated
  - Use GOOSE message with GGIO emulating the contacts between the device (PU/SCU/BCU) interfacing the equipment and a simulation tool

Test plan

- Phase 1– Test the integrated application design (Monday)
  - Verify that every IED is configured with the expected data model and that the data can be reported to the client
  - Verify that the GOOSE / SV messages are present as configured
  - Verify that the GOOSE / SV messages are received as expected
  - Scheme testing
- Phase 2 – Individual tests (normal behavior) (Tuesday)
- Phase 3 – Maintenance tests (Wednesday AM)
  - Reconfiguration
  - Verification (individual)
  - Scheme testing

Test plan

- Phase 4 – Individual tests (Wednesday PM)
  - Including IED failure / power down
- Phase 5 – Time tests (Thursday AM)
- Phase 6 – Network testing (Thursday PM)
- Phase 7 – individual testing (Friday)

Scheme testing of integrated application

- Line 1 fault with successful reclosing
- Line 2 fault with reclosing on fault and permanent trip
- TXA fault with successful trip
- TXB fault with failing HV breaker
- BUS230 fault
- Feeder A1 fault – BT open
- Bus A fault – BT open
- Feeder B1 fault – BT closed, with failing breaker B1
- Bus B fault – BT closed
- Feeder A2 fault on transfer bus – BT open

christoph.brunner@it4power.com