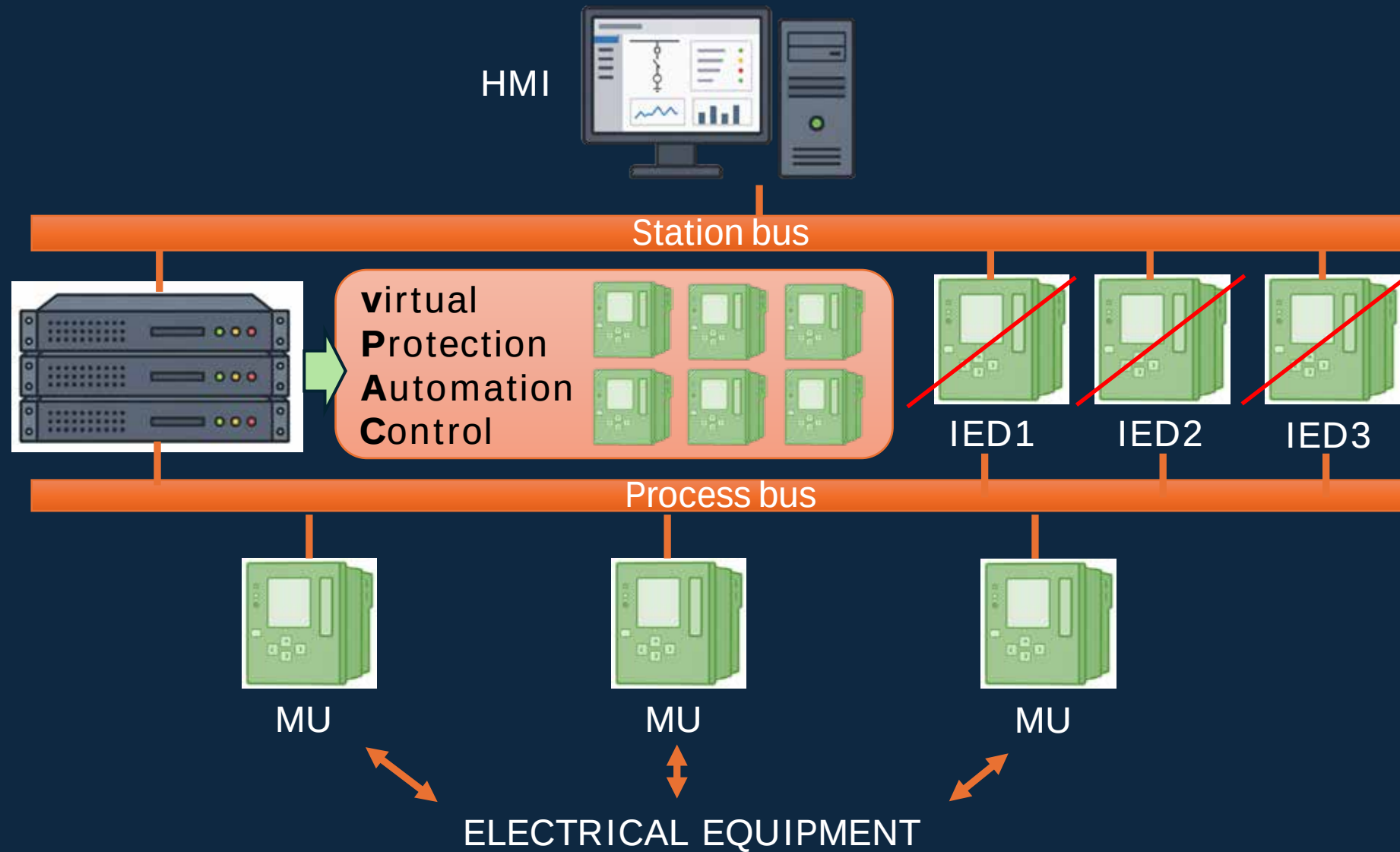


RTDS simulation for IEC 61850 process bus

- u Konstantin Goriachevskii
- u Siemens Energy, Germany



Virtual and centralized PAC



The difference?

Software-defined substation

- ✓ All IEDs in one solution
- ✓ General-purpose hardware
- ✓ Only digital data, no copper wires
- ✓ IEC 61850 SV+GOOSE+MMS
- ✓ Top-down engineering



✓ One vendor



**Centralized
CPC**



✓ Multi-vendor



**Virtual
vPAC**

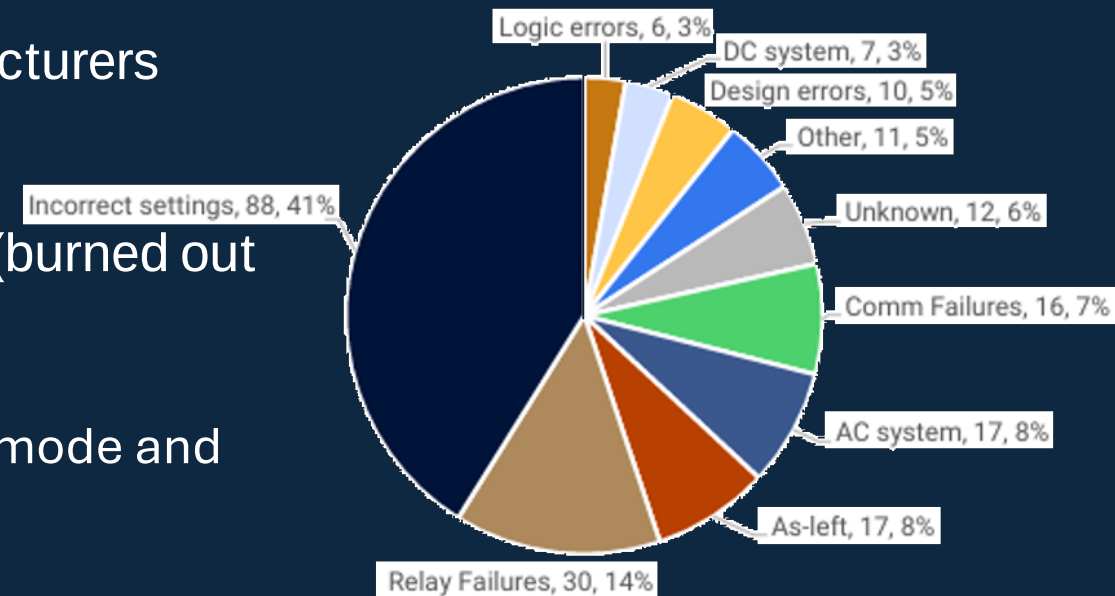
Deploying a PAC system

- During commissioning of a new substation, we test each protection function and each IED separately using a current/voltage injection devices (e.g. Omicron CMC)
- Engineering and commissioning of a high-voltage AC substation PAC system usually includes calculation, parametrization and testing stages.
- Commissioning tests are performed for each **individual** IED and validating every function **independently**.
- **No system-wide tests are performed**



Human factor

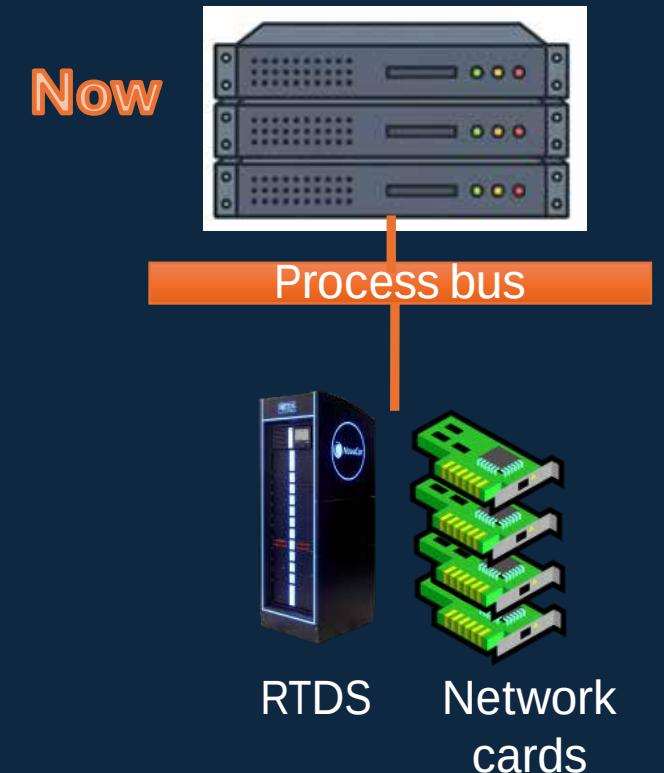
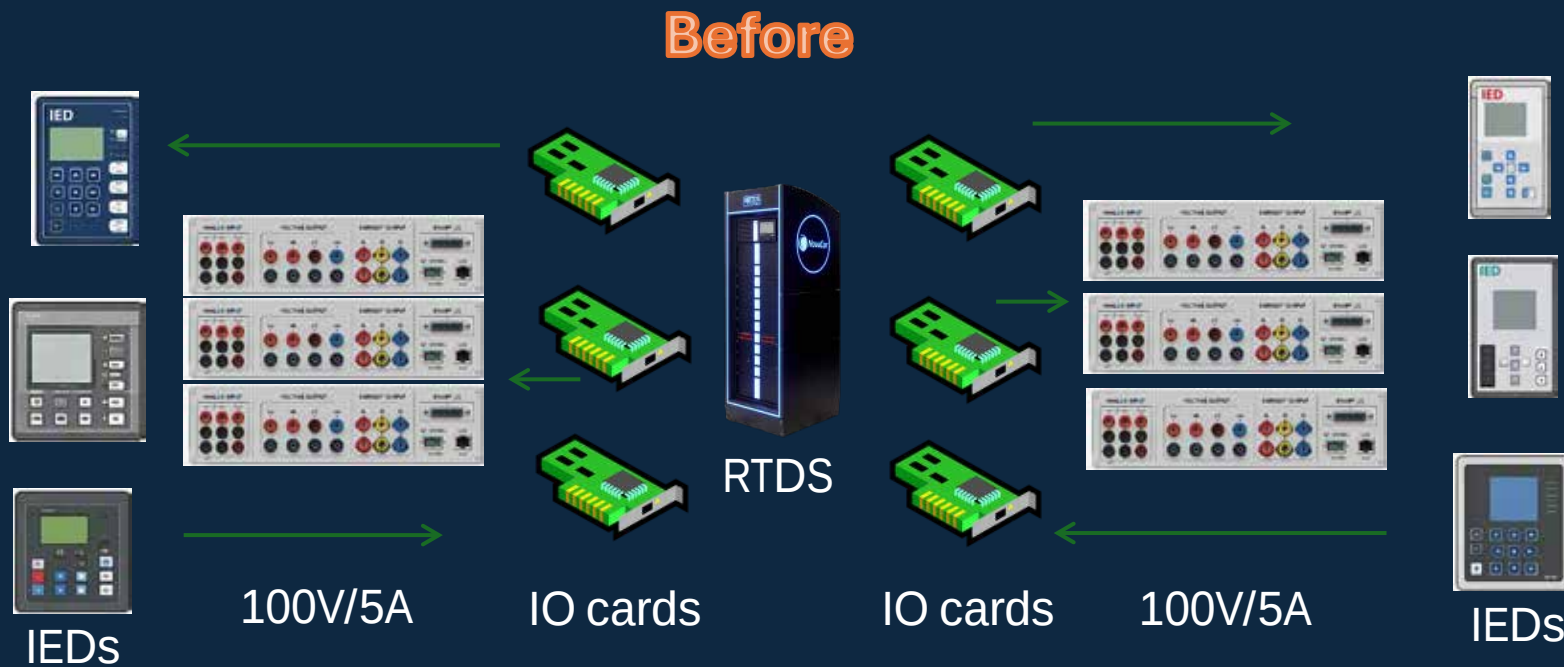
- This is a well-established approach, but cross-element behaviour and overall system performance remain untested.
- According to grid operator reports, about 50% of protection misoperations are due to incorrect settings and human mistakes.
- Practical examples (beyond typos):
 - “default values” – parameters left out to manufacturers competence (e.g. 10 Hz/sec in load shedding)
 - user-defined logic schemes
 - wrong CT ratios mismatching real fault currents (burned out secondary circuits)
 - inter-/extrapolation errors when using curves
 - conflicts when switching between remote/local mode and setting groups



Source: WECC - 2024 Misoperations Report

Tests – before vs. now

- With hundreds of hardware IEDs, it was almost impossible to perform integrated tests.
- vPAC enables a compact system to be tested in a lab even before or during the commissioning.



Simulation

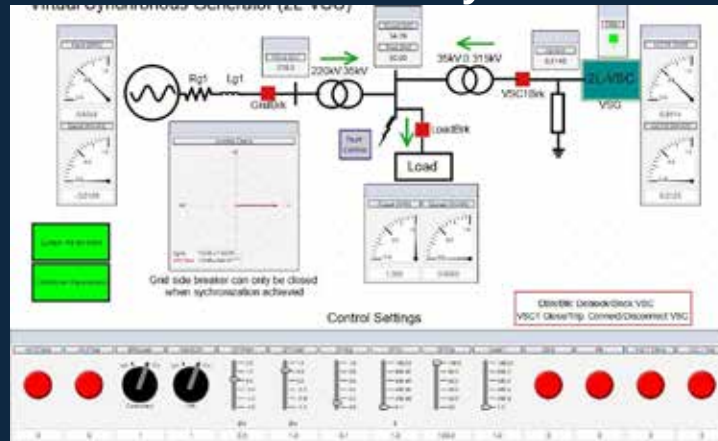
- Real-time simulation with multiple network cards streaming data from the model.
- PAC system is hosted on a target computer HW in a full operating state and connected to RTDS which reproduces the realistic substation equipment response in form of:
 - IEC61850 Sampled Values current and voltage measurements
 - IEC61850 GOOSE messages for time-discrete events.
- The required initial data for primary equipment modelling is provided from short-current analysis and settings calculation stage, and the switchgear interface description is defined by IEC 61850 SCL.

ETAP/

PowerFactory/
PSSe

CT/VT models

MU Binary
inputs/outputs



RTDS



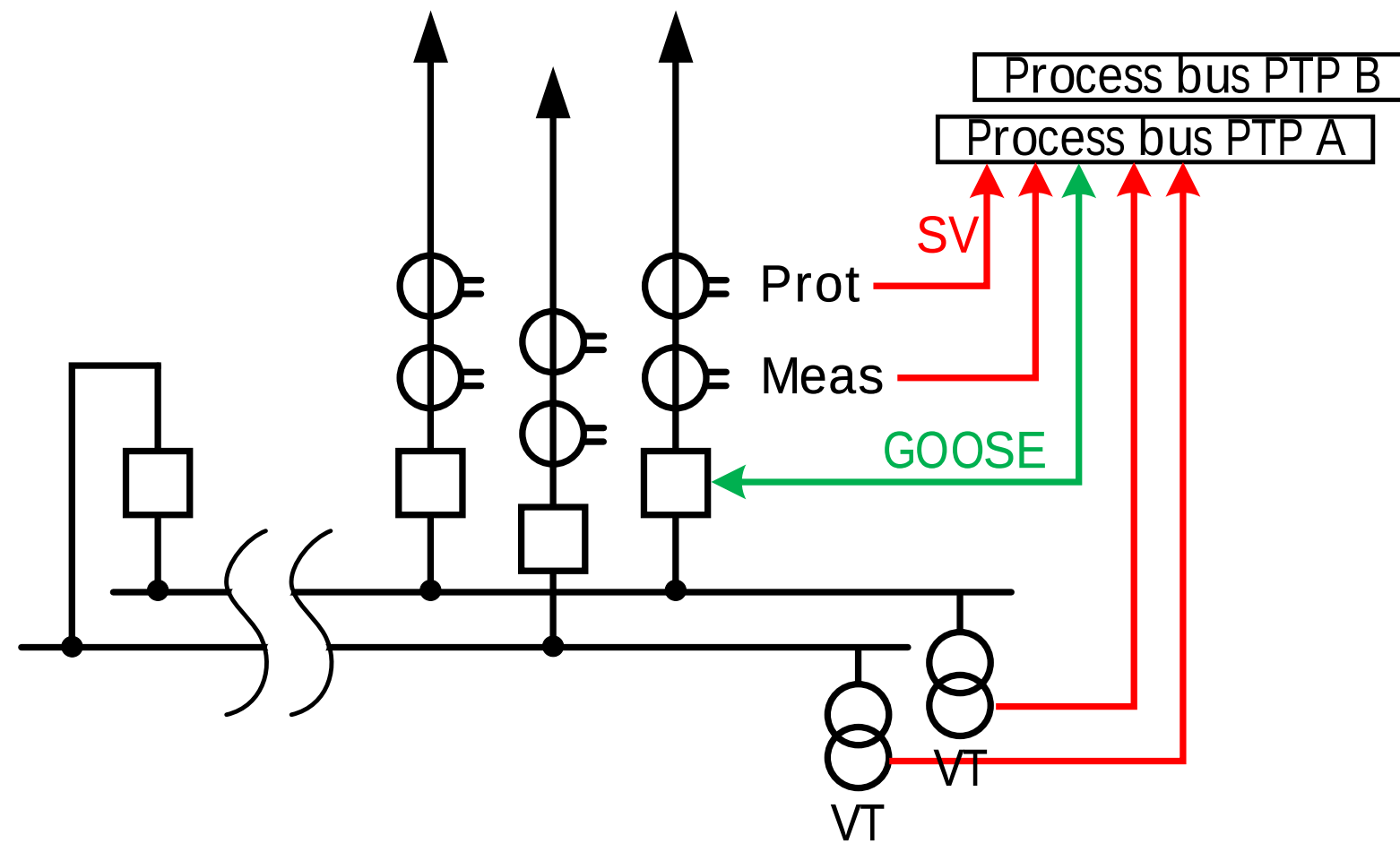
GTNETx3



vPAC

Operational
state

Example



Peculiarities

- RTDS GTNETx3 supports per port:
 - 2 flexible SV streams (up to 24 channels)
 - 4 IEDs/16 GOOSE control blocks/512 data objects,
- For a template 20 bay substation required ~8 GTNETx3 cards:
 - >10 ports for 20 current + 2 voltage SV streams (light edition)
 - >5 ports for 20 bay controllers (aka binary in-out IEDs)
- For real cases up to 60 bays: 24 GTNETx3 cards – exactly 1 Novacor
- 1 Gbit network also would support ~50-60 SV streams (light edition)
- Don't forget the permanent **measurement** 256 points/cycle traffic!

Workarounds

- For optimization, several SV streams can be combined into one big flexible stream:
 - + Less packet-per-second load for network and vPAC
 - -- More internal routing inside the vPAC
 - -- No MAC/VLAN/AppID filtering
- Same for GOOSE, multiple IEDs can be combined as “logical devices” into one extended with same
- Only functional validation is possible, no process bus validation
- Solution only to increase the number of cards (or 1Gb?)
- GTSYNC compatibility with different PTP clocks in slave mode

Benefits

Integrated testing allows us to :

- identify selectivity issues
- test overall coordination
- validate settings
- reproduce the precise process bus network load
- obtain realistic process bus delay

Integrated tests are a common approach for complex control systems and HVDC

Disadvantages:

- Additional stage
- Requires RTDS and engineer
- Makes sense for a complex 400+ kV project, but not for 35 kV

Conclusion

- Due to compactness of vPAC solutions, additional integrated Acceptance Tests are possible now
- ~50% of protection misoperations are due to the incorrect settings
- Integrated testing allows reduce the number of tests
- Before such tests were barely possible for usual PAC deployments due to the large number of IEDs and testing equipment involved
- Virtual (centralized) PAC allows for such tests in a lab/on site
- RTDS model consists of primary equipment data and IEC6180 .SSD
- Testing vPAC + Process bus + RTDS in a fully operational state (“Digital Twin”).