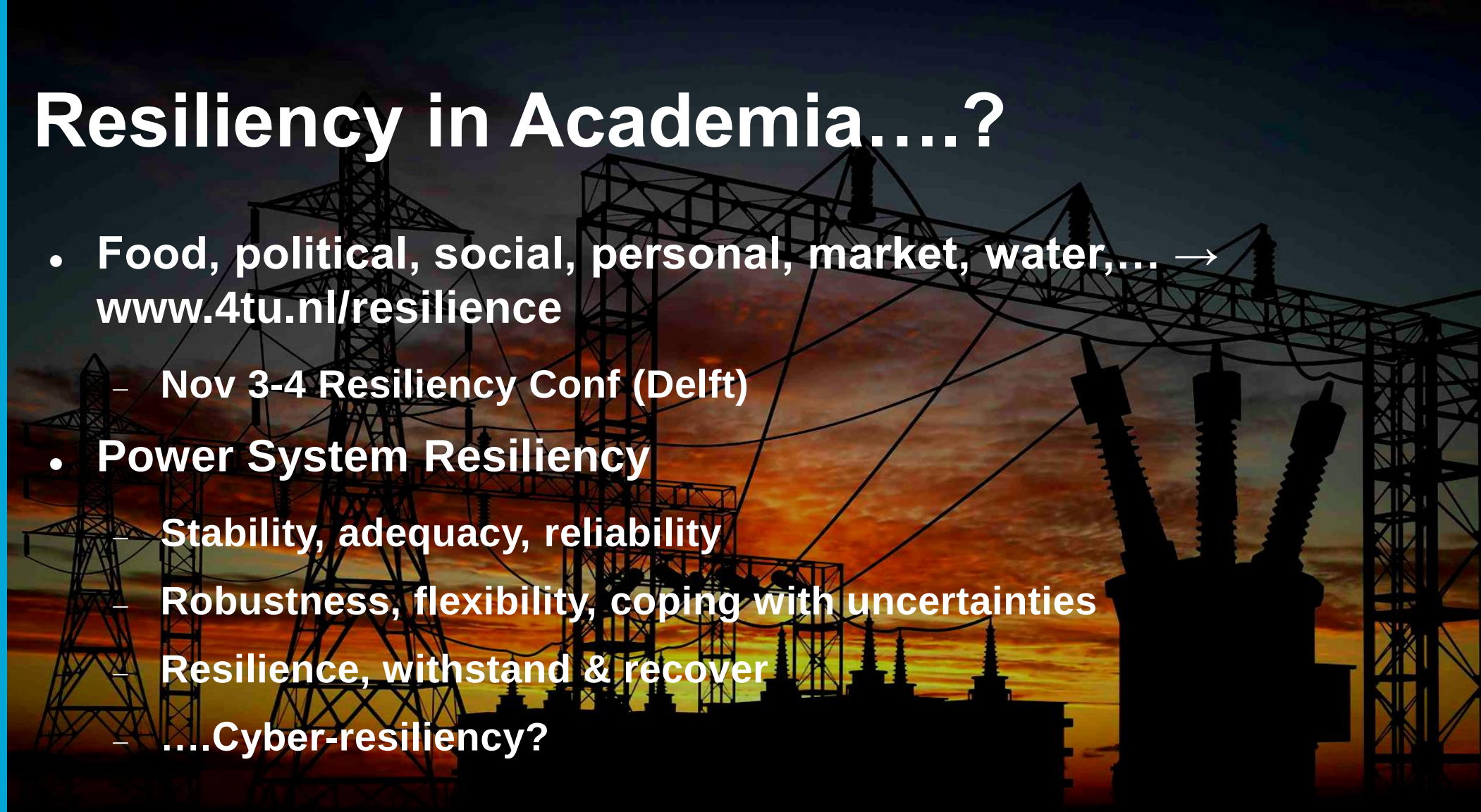
Academic view on resilience

CIGRE C0 Seminar 2022 on
critical infrastructure and cyber security

Peter Palensky
TU Delft

Resiliency in Academia….?

- Food, political, social, personal, market, water,… → www.4tu.nl/resilience
  - Nov 3-4 Resiliency Conf (Delft)
- Power System Resiliency
  - Stability, adequacy, reliability
  - Robustness, flexibility, coping with uncertainties
  - Resilience, withstand & recover
  - ….Cyber-resiliency?



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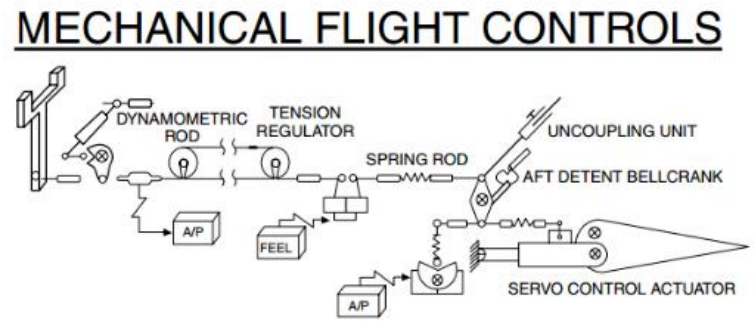
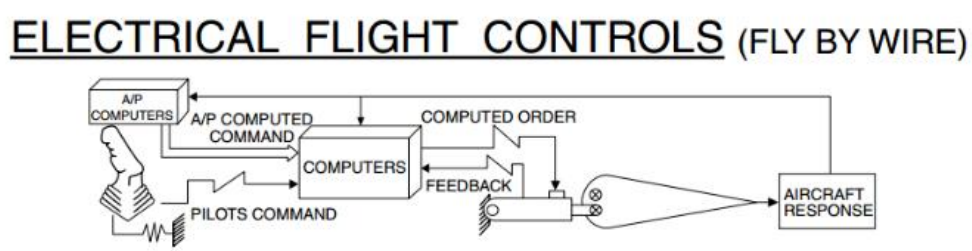
Crystal Ball for Power Sector!

- Mil, Avionics, Automotive, IT(?)
  - Cruise missile, A320, Tesla, AI/ML
- Fly-by-wire
- Redundancy
- Car2X communication
  - Cyber-sec?





Web3: flat, distributed, virtual?

Resilient!

Gold

Fiat

Crypto

Physical

Central Agreement

Distributed Agreement

Local Fuel

Power System

Energy Community

ICT: benefit or threat to resiliency?

- Active assets ownership diversity
- Digital identity management
- Supply chain for digital assets (firmware update, patches)
- Admin, scalability,…
- …stay with centralized card-house?

Image: NREL

Question...

Digital Substations, IEC 61850, PMUs, …

good (GREEN) or

bad (RED)

for power system resiliency?

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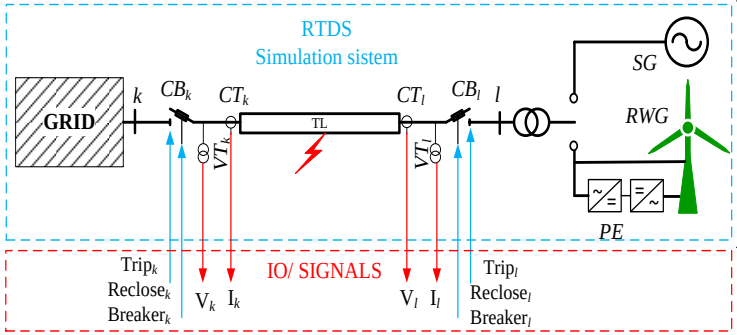
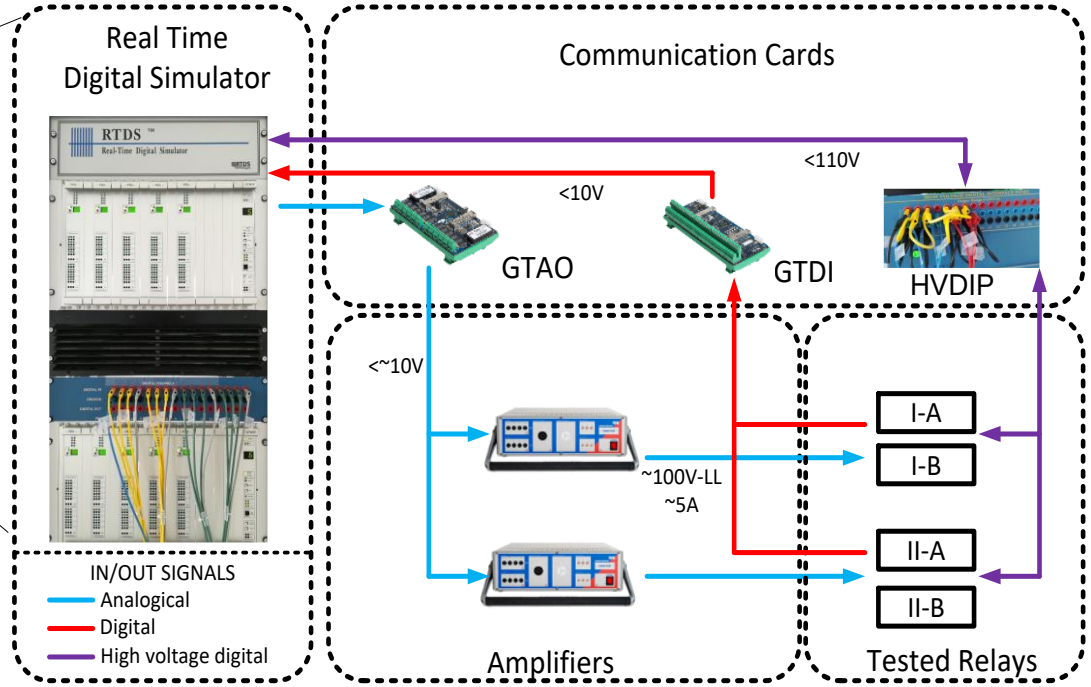
Activities in Academia

- Research
  - “Old”: risk assessment, stability, reliability,...
  - New: intrusion detection, swarm behavior, planning and operations under uncertainty, system-of-systems,...
  - Cyber-physical (social-stochastic-economic…) system
  - **Master complexity**: analytical, data-driven, numerical
- Education
  - Students, future and current workforce
  - Training with digital twins in labs

Ex 1: numerical experiments with power system protection

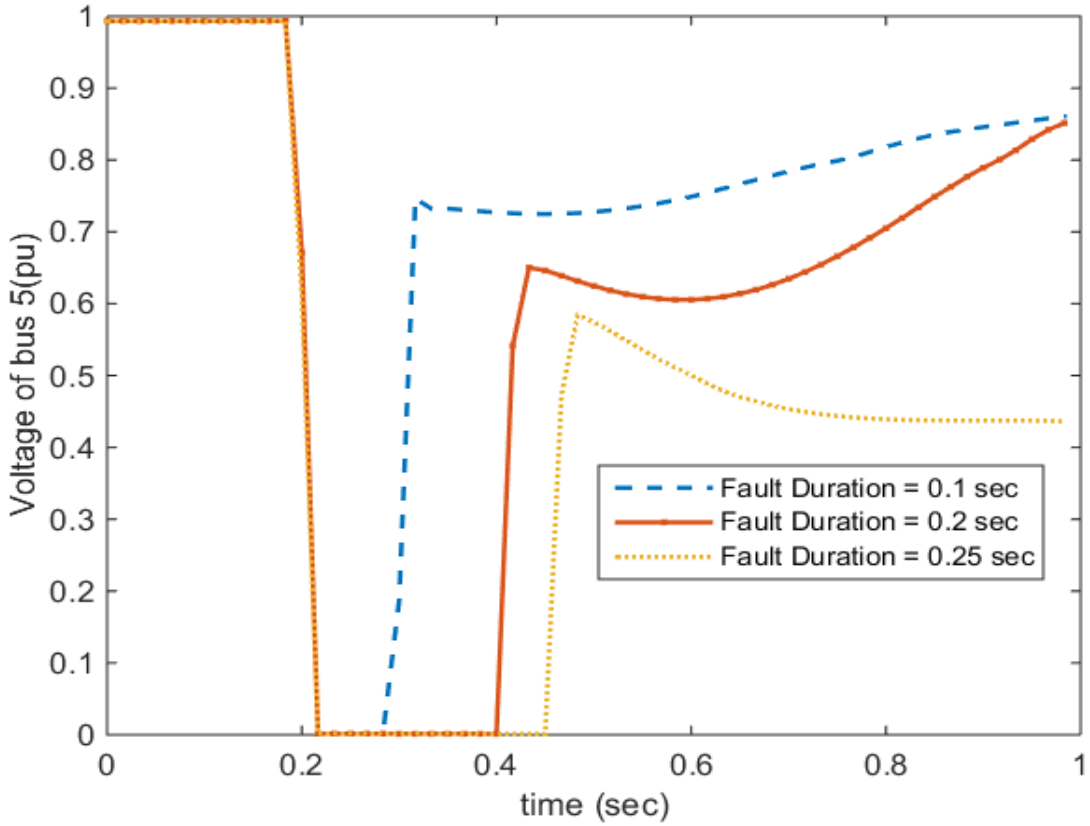


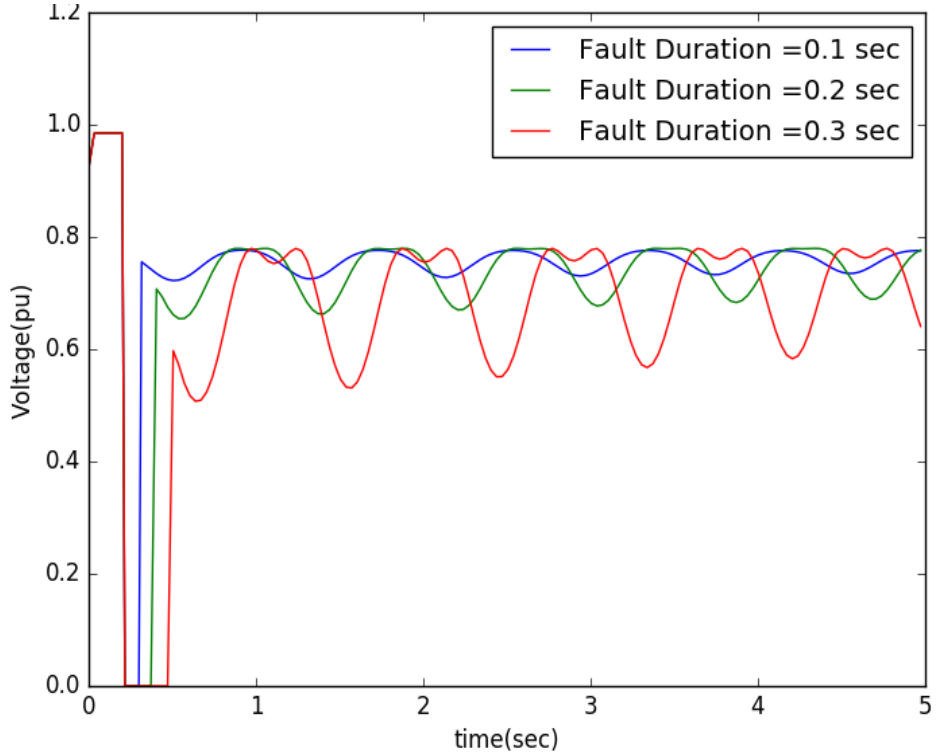


- Massive batch processing
- Interfacing?
- Open Benchmark Cases?
- Open Data Sets?
- Confidentiality?

HIL: Hardware-in-the-Loop

Ex 2: Forecasting Voltage Stability

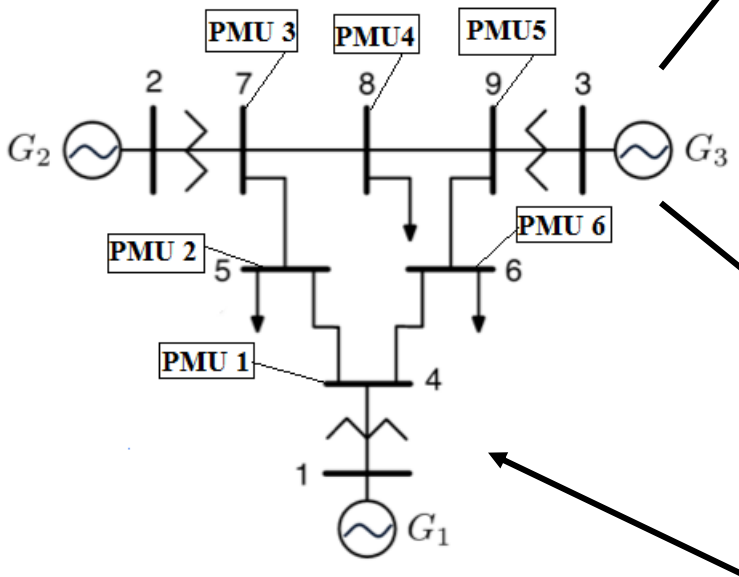




Faster-than-real-time twins?

validation?
coverage?

Real System



Identification → Model

AI/ML

Signatures

Surrogate

Offline Learning

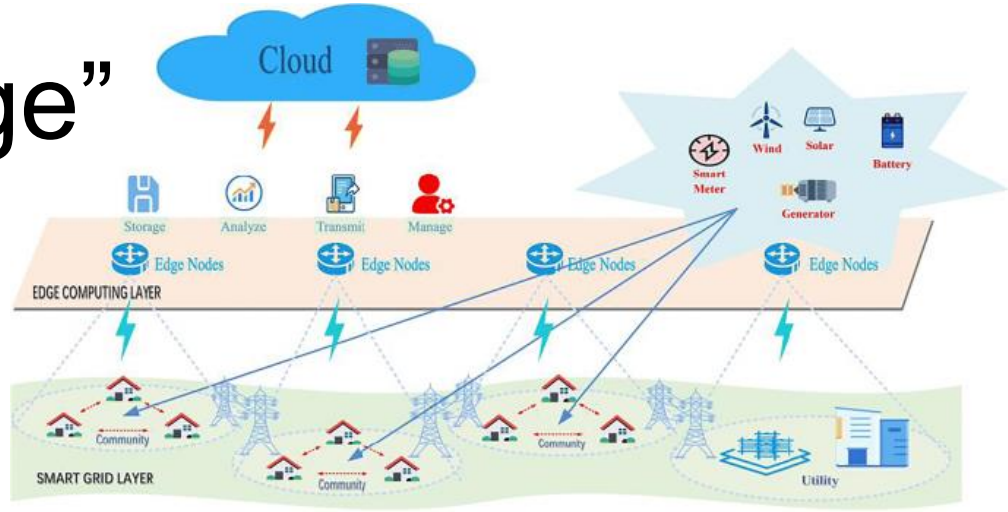
Non-RT

Detection → (smart) Forecast → Scenario

incl. remedial actions?

Classification → Robust Decision

Ex 3: Smart “Grid Edge”



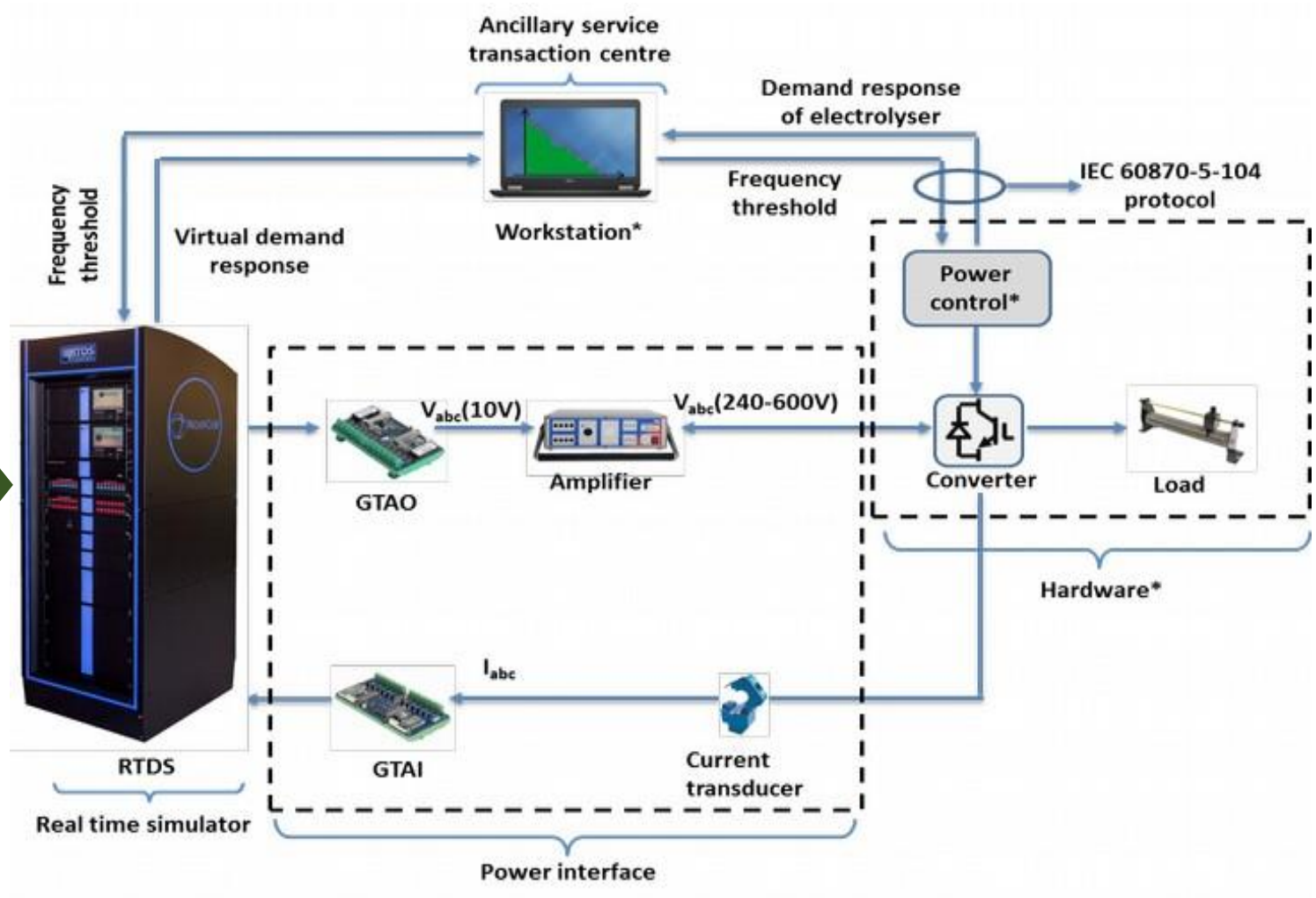
- IoT-enabled
  heat-pump, PV panel,
  EV charging pole,
  A/C, batteries,…
- Contribute to ancillary and local services
- Reliability? Statistical methods...
- Ownership of data, functions,…?
  - EU “Data Act” in preparation (GDPR for IoT)
  - New role for grid companies?

IoT: Internet of Things
PV: Photovoltaics
EV: Electric Vehicle
A/C: Air Conditioning
GDPR: General Data Protection Regulation

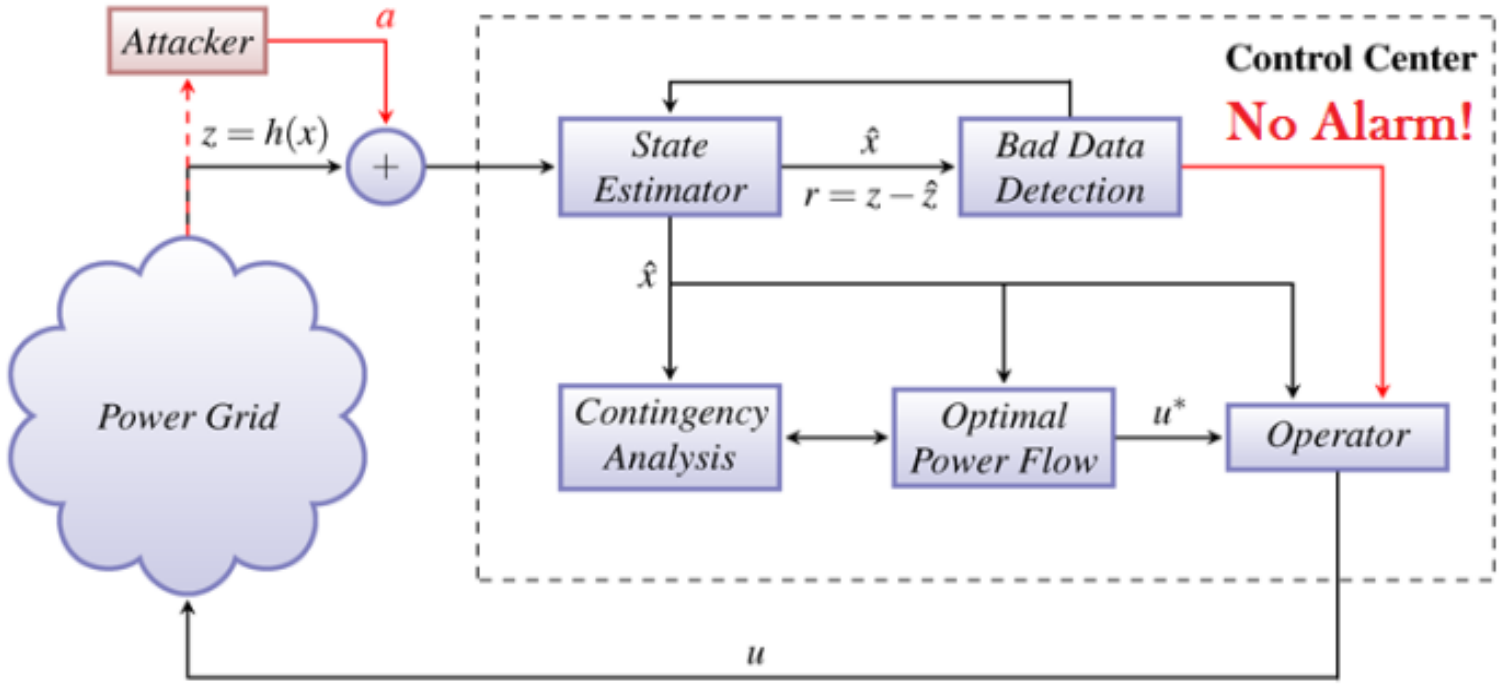
Ex 4: Ancillary Services of Hydrolyzers

EMT system model

North Netherlands (year 2030)

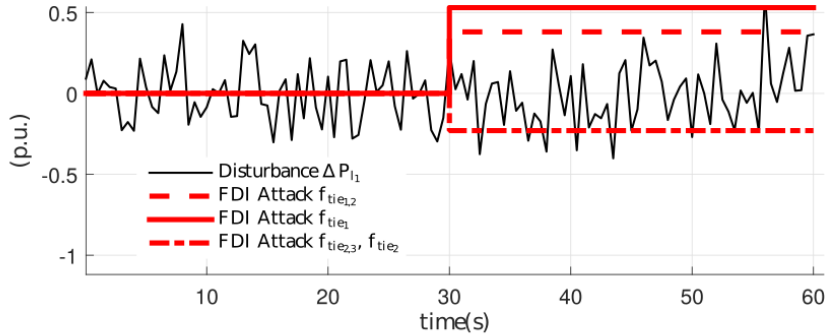


Ex 5: Sophisticated attacks coming...



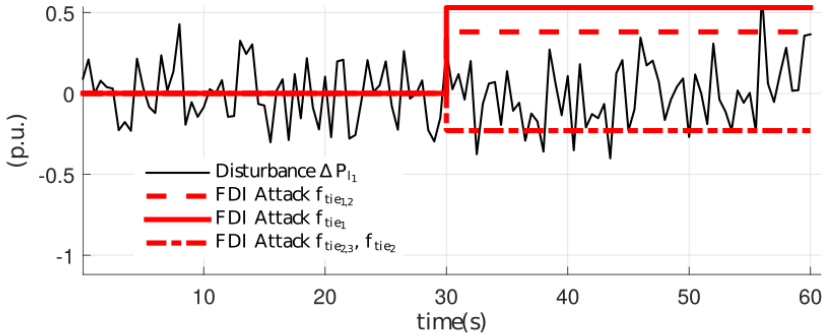
- Energy Management System
- Stealthy Attacks
- Theft, vandalism warfare
- Cascading effect

Cyber-physical attack

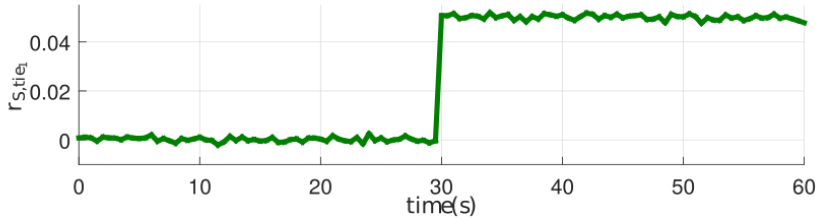


FDI: false data injection

Cyber-physical attack



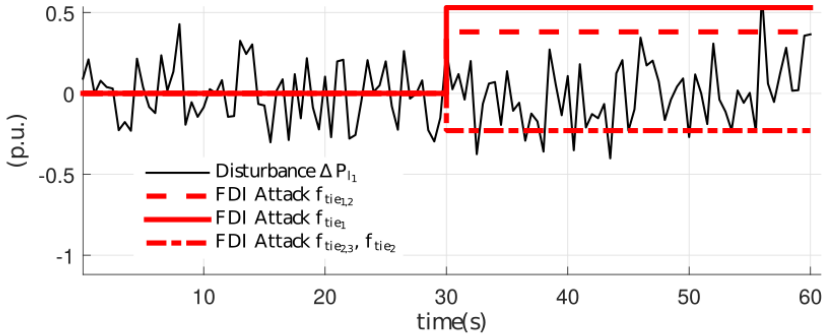
(a) Load disturbance and unstealthy attack



(c) Residual of static detector under unstealthy attack

FDI: false data injection

Cyber-physical attack: undetected



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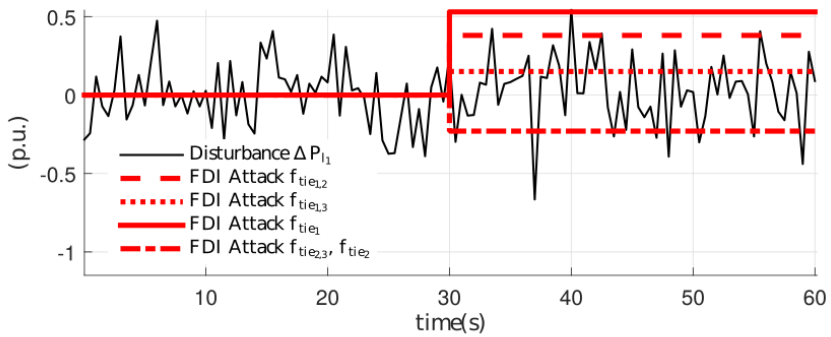
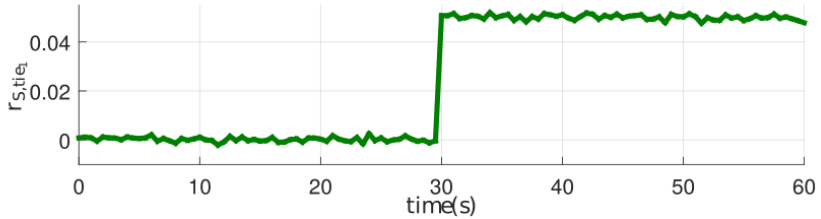
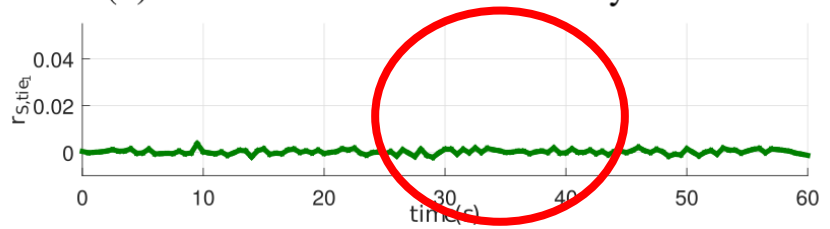


(b) Load disturbance and stealthy attack



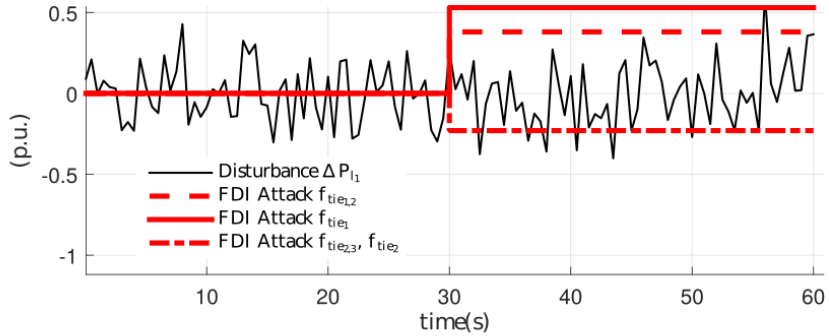
(c) Residual of static detector under unstealthy attack



(d) Residual of static detector under stealthy attack

FDI: false data injection

Cyber-physical attack: detected (analytically!)



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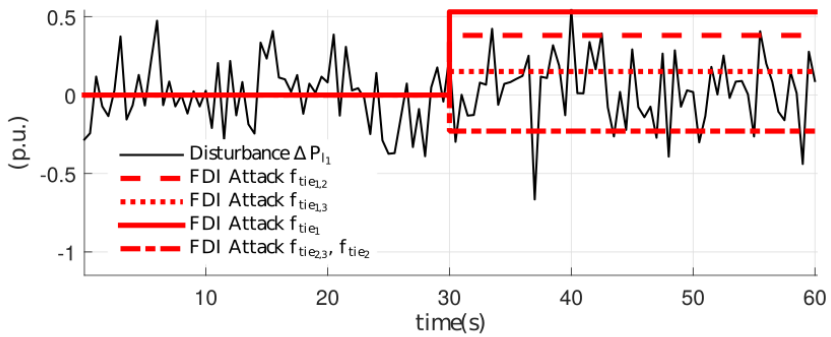
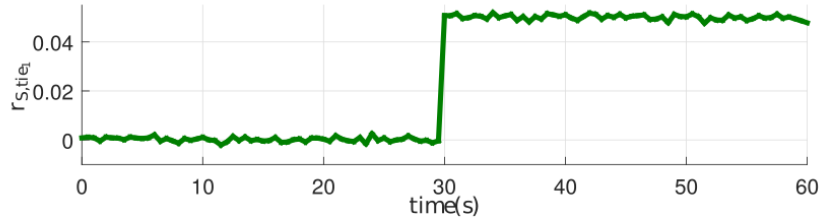


(b) Load disturbance and stealthy attack



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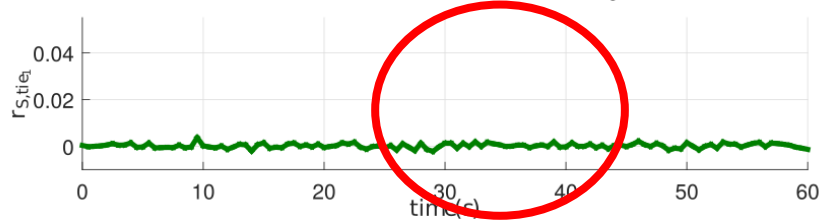

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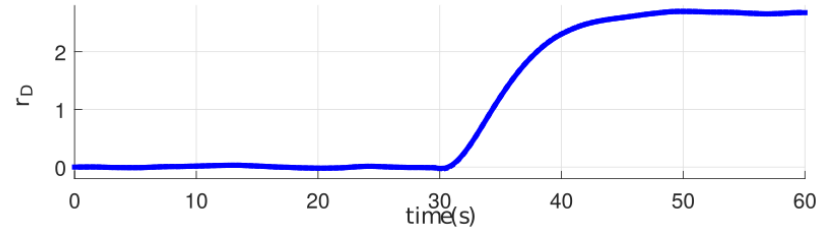
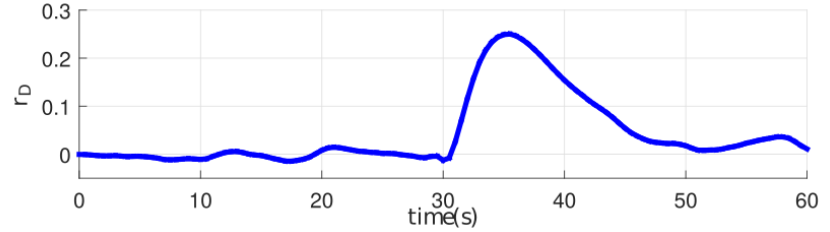


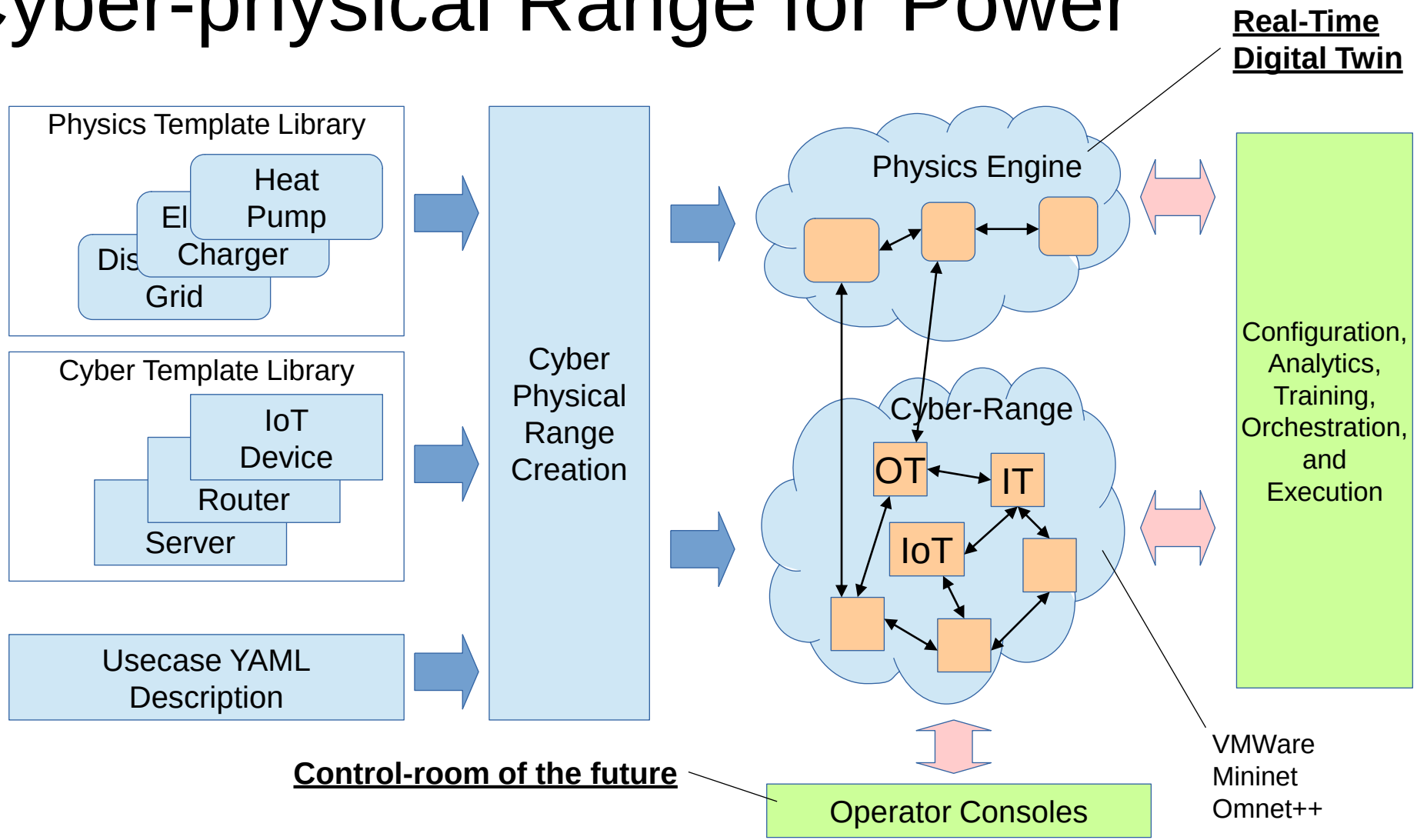
(e) Residual of dynamic detector under unstealthy attack



(f) Residual of dynamic detector under stealthy attack

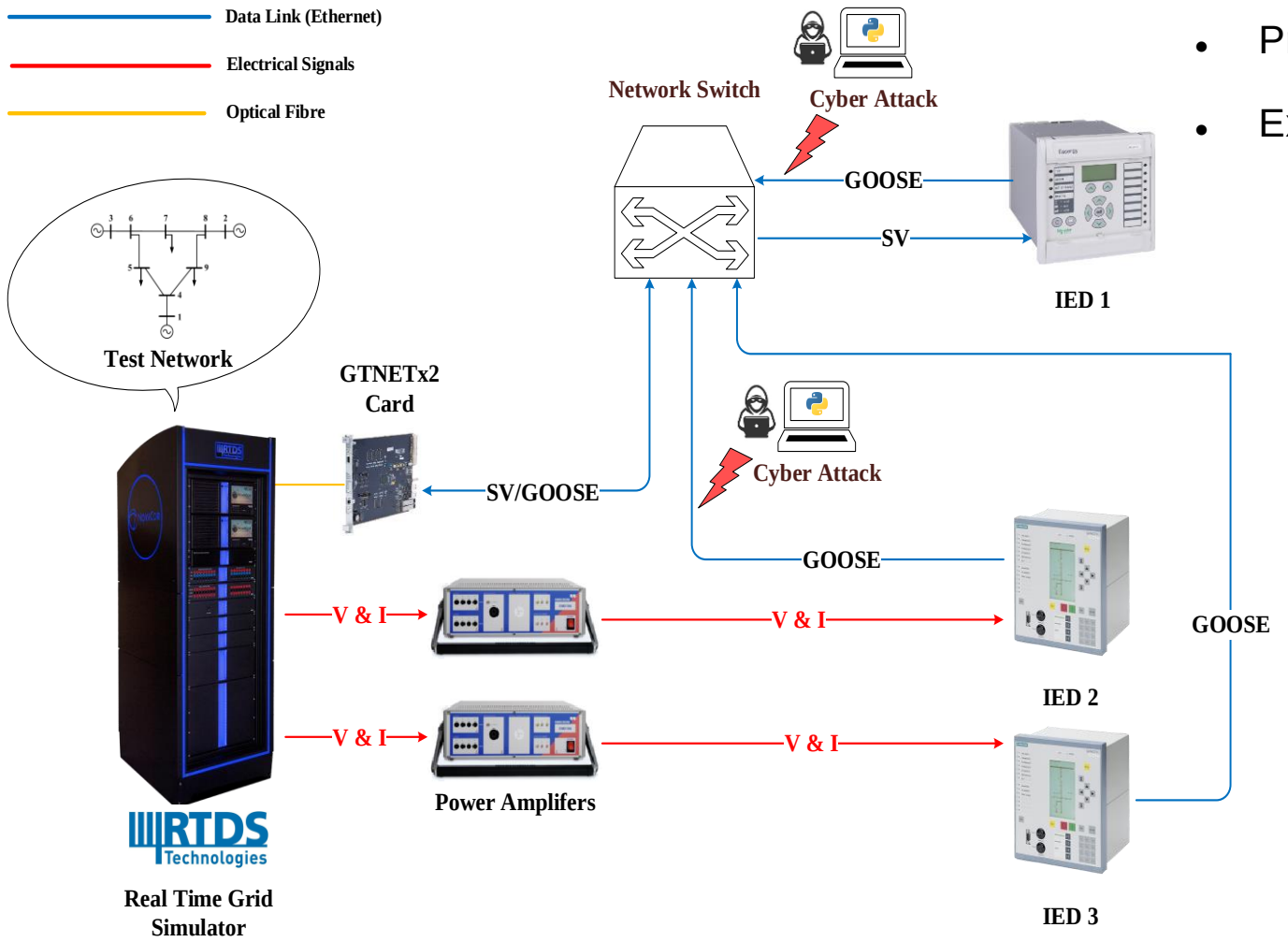
FDI: false data injection

Cyber-physical Range for Power



Cyber Attack Analysis

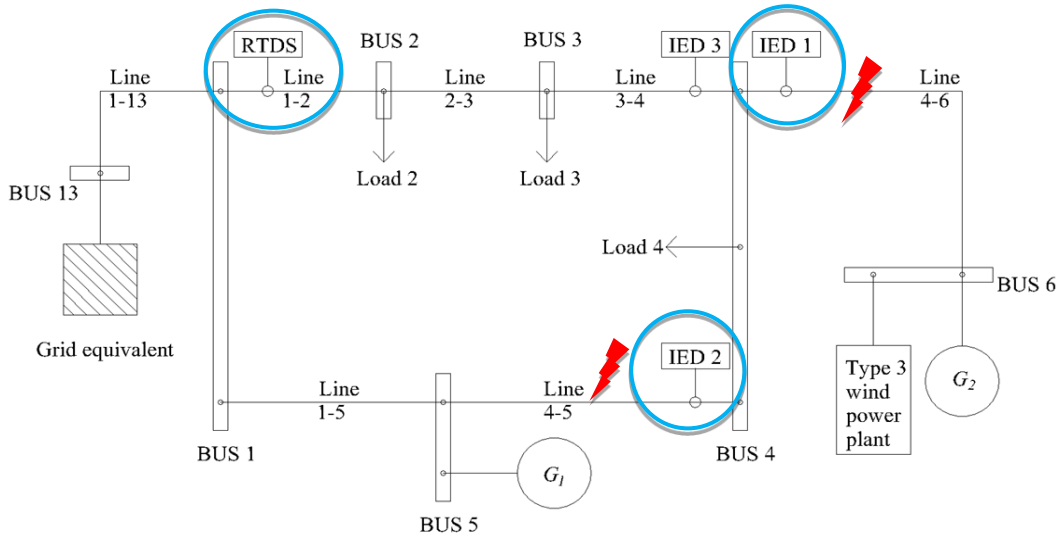
- Reconnaissance
- Preparation
- Execution



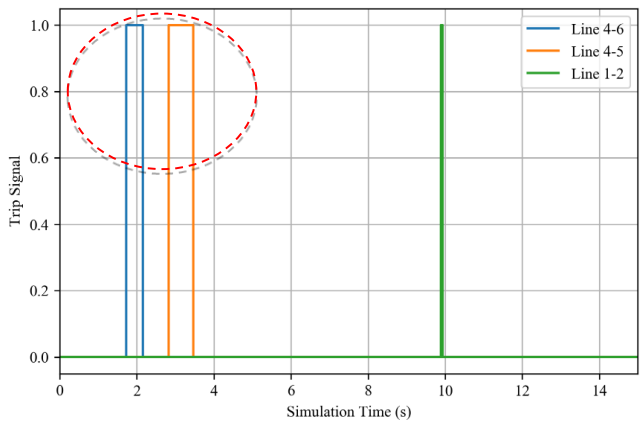

```
    Type: IEC 61850/GOOSE (0x88b8)
GOOSE
    APPID: 0x8000 (32768)
    Length: 156
    Reserved 1: 0x0000 (0)
    Reserved 2: 0x0000 (0)
  goosePdu
      gocbRef: P446_SVSystem/LLN0$GO$gcb01
      timeAllowedtoLive: 2001
      datSet: P446_SVSystem/LLN0$OPGOOSEDataset
      goID: P446_GOOSE
      t: Mar 17, 1994 22:13:49.941999971 UTC
      stNum: 1
      sqNum: 23628
      test: False
      confRev: 3
      ndsCom: False
```

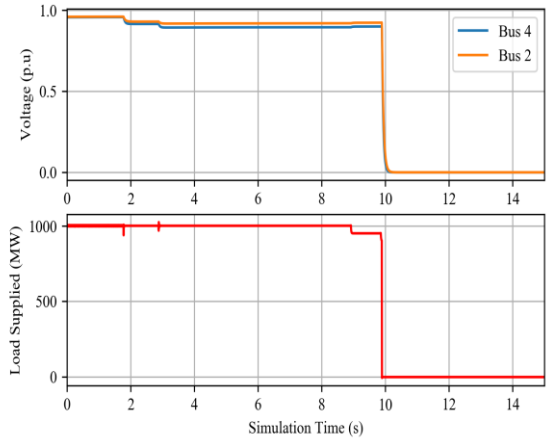
Wireshark snippets GOOSE data frame

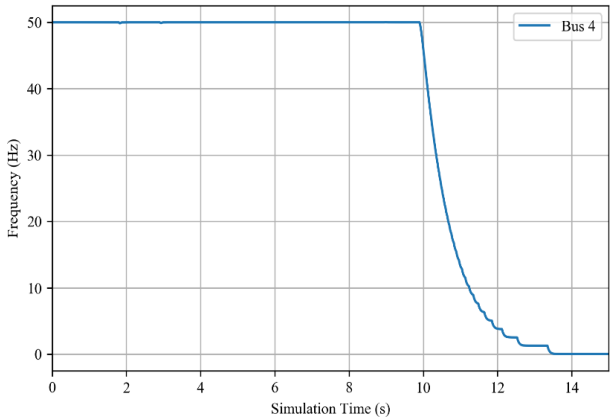
Coordinated Attacks (N-1 anyone?)



- Coordinated GOOSE cyber attack on IEDs 1 and 2, type “Flevoland” ;-)
- Lines 4-6, 4-5 disconnected. G1 lost
- Voltage drops below limit of 0.92 p.u
- Overload protection trips line 1-2 (1.1 p.u, delay 7s) after cyber attack
- Leads to cascading failure and blackout







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Take aways

- Academia is neither army nor consultant
- Academia is a partner that grows with you
- Resilient digital transformation “done right”?
  - Security by design, auditable
- Complexity: there is help!

Question...

Self-organization, distributed control, market-based control,…

good (GREEN) or

bad (RED)

for power system resiliency?


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MDCCCXLII