Comprehensively Analyzing the Impact of Cyberattacks on Power Grids

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https://github.com/fkie-cad/wattson

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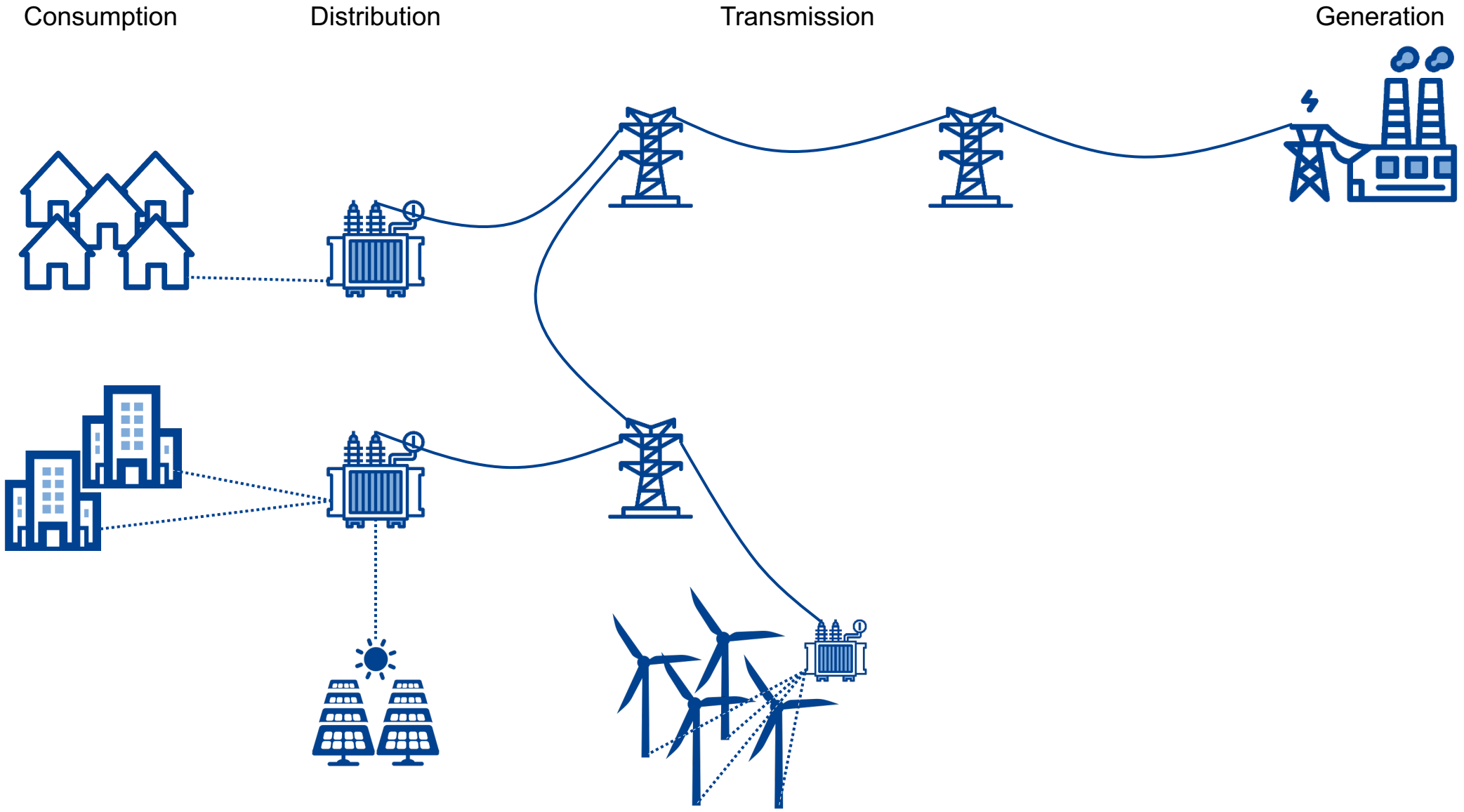
Digitized Power Grids are Vulnerable



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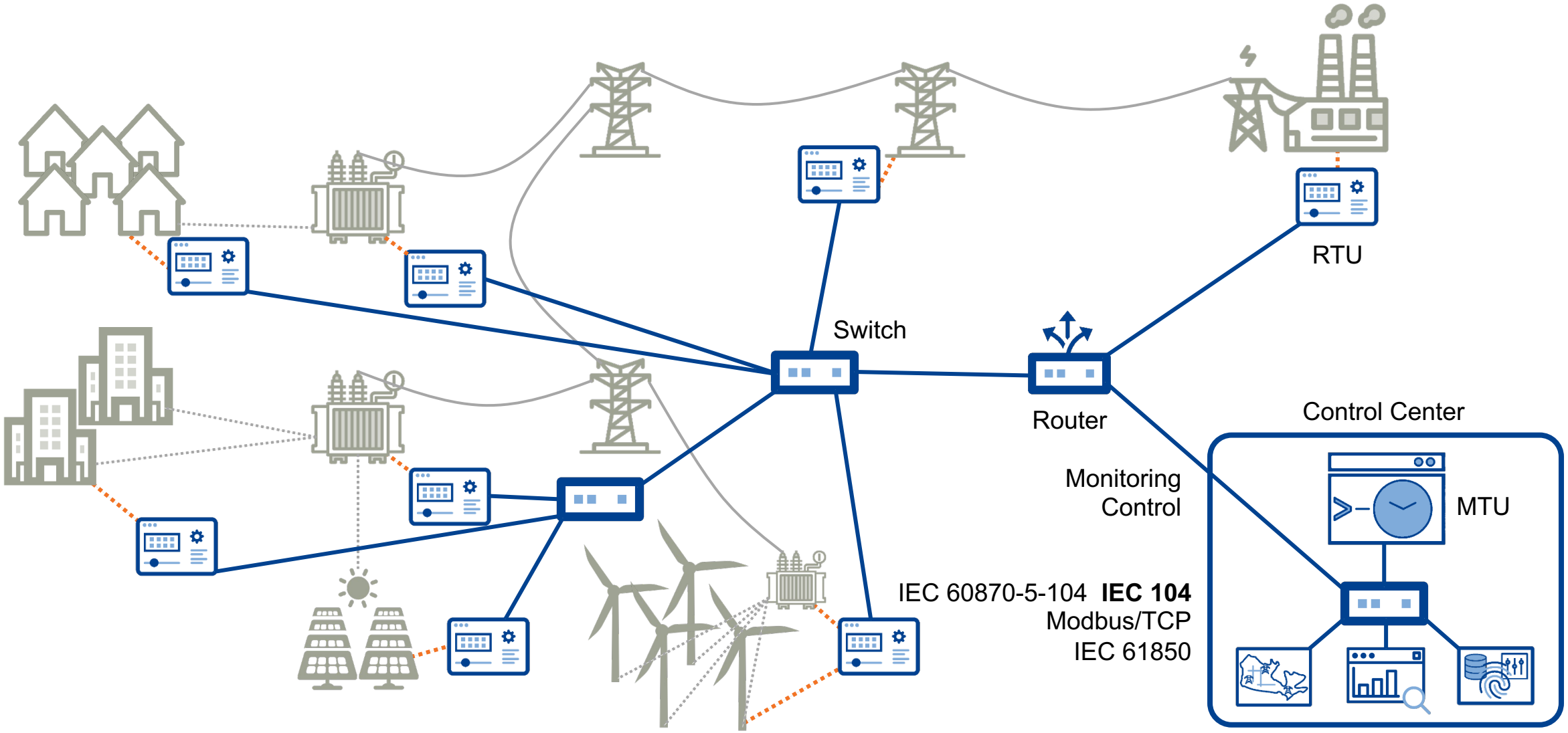

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Vulnerabilities and Common Attacks

Compelling target
- Critical infrastructure
- Physical consequences

Physical access
- Unmanned facilities
- Geographic scale
- Multiple actors

Limited security
- Encryption, authentication
- Network segmentation

- **Multiple attack types in related work**
  - Demand manipulation
  - Denial of service
  - Control command issuance
- **Isolated evaluations**
  - Mostly focus on one attack type / class
  - Mostly considering only one domain (power grid *or* network)

	Attack Type	ICT	Power Grid
Phys.	Device Disconnect		[36], [91]
	Demand Manipulation		[37], [90] [89], [103]
Syn.	Denial-of-Service	[3], [13], [66] [108], **[92]**	**[92]**, [2], [30] [33], [56], [109]
	Replay	[51], [62], [107]	[39], [109], [112]
Sem.		[79]	[2], [39], [99]
	False Data Injection	[13], [43], [45] [44], [51], [102]	[2], [19], [56], [77] [17], [47], [61], [111] [24], [41], [54], [85]

Sophisticated cross-domain evaluations of effects of cyberattacks missing

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Methods for Realistic Cross-Domain Evaluations of Cyberattacks

The real power grid

\+ Maximum realism

\- **Risky**
\- Expensive
\- **Infeasible**

Laboratory setups

\+ **Great realism**
\+ Real devices

\- Limited scalability
\- Inflexible topologies
\- Costly

Simulations

\+ Good realism
\+ Scenarios **flexibility**
\+ **Scalability**

\- Realism depends on model
\- Abstraction

Existing simulation environments

- Often specific focus / use case
  - No **real network traffic**
  - Insufficient **accuracy** (for one domain)
  - Limited **scalability**
- Usage of proprietary hard- or software
  - Limited **availability**

Our proposal

WATTSQN

- Open source
- Co-simulation environment
- Cybersecurity focus

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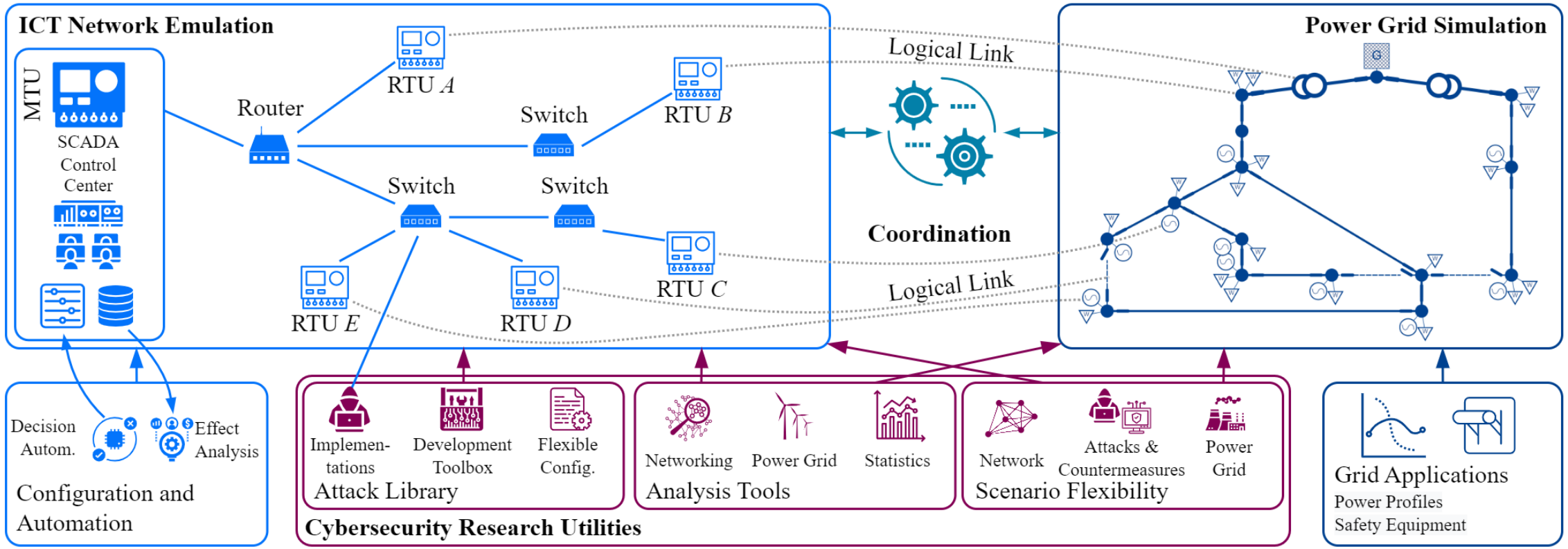
Wattson: A Cybersecurity Research Testbed for Power Grids



- **Network emulation** Containernet-based
  - Realistic network traffic down to Layer 2
- **Power grid simulation** Pandapower-based
  - Static on-demand power flow computation
- **Transparent coordination**
  - Interactions between ICT and grid components
- **Cybersecurity research utilities**
  - Attacks, analyses, configurations

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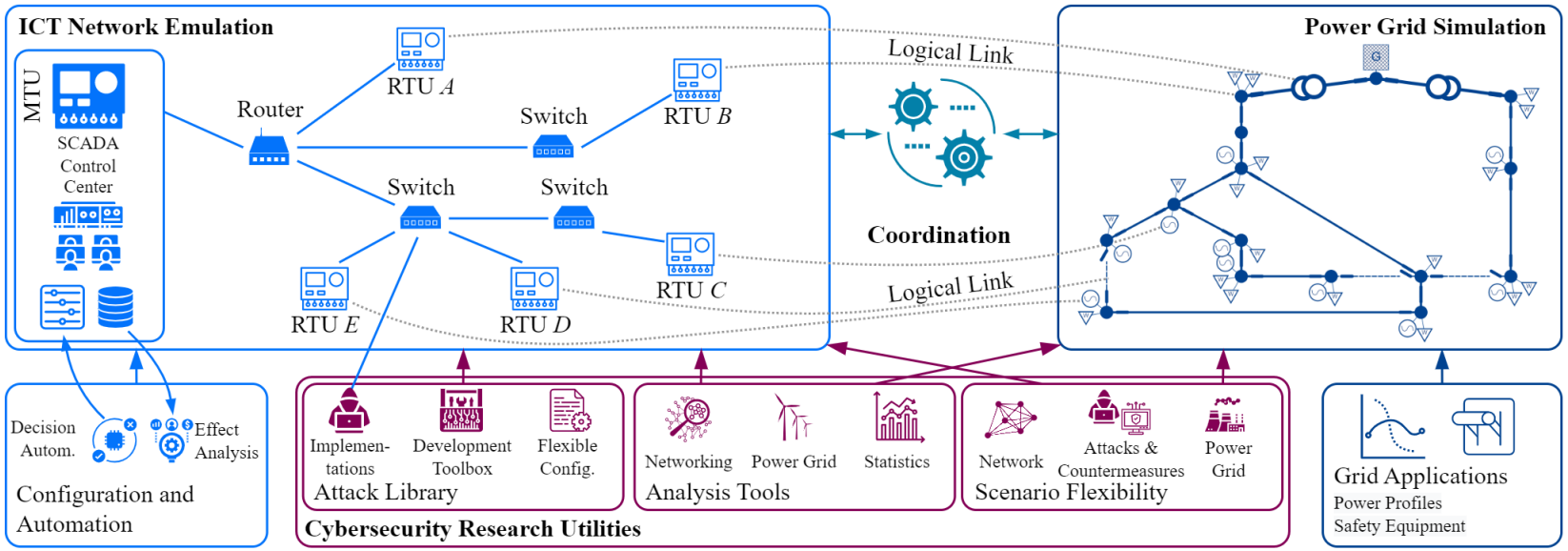

WATTSON is available on GitHub

https://github.com/fkie-cad/wattson

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Wattson is Accurate and Scalable

Validation against laboratory grid at RWTH Aachen Univ.

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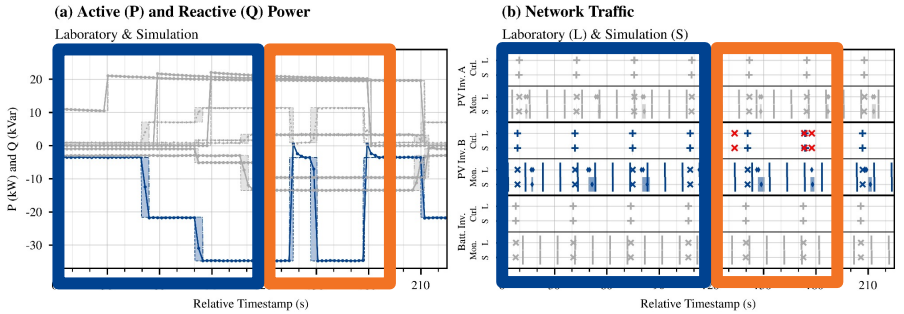
Wattson is Accurate and Scalable

- **Recreate laboratory topology and scenario in Wattson**
  - Normal behavior
  - MitM-based attack
  - Compare laboratory and simulation



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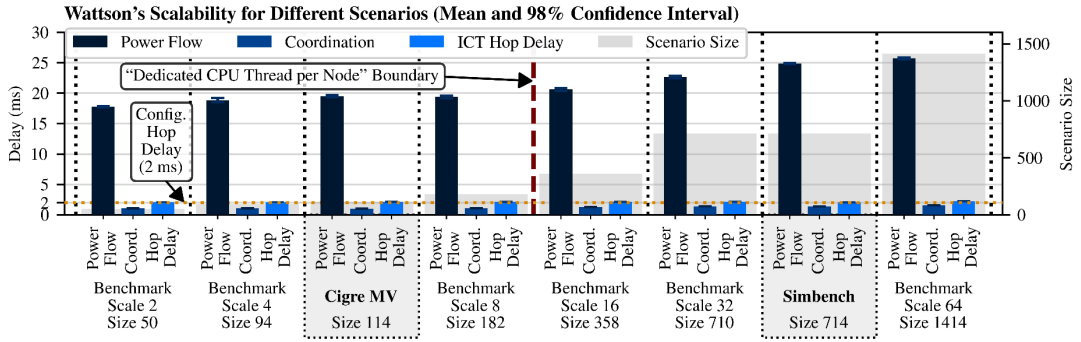
Accurately matching behavior under normal and attack conditions

Scalability

- We evaluated Wattson‘s scalability with synthetic and reference power grid topologies
- Suitable **performance** for evaluating cyberattacks
- **Scales** to realistic grid sizes



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Evaluating Cyberattacks against Power Grids with Wattson

Destruction of equipment

Interference with network traffic

Manipulation of application layer traffic

Physical Attack

- Destruction of substation
  - Power grid assets
  - ICT equipment

Flooding

- TCP SYN flooding
- Affects multiple RTUs
- Saturation of network links

Industroyer

- Secondary IEC 104 client
- Issues control commands
- Disconnects large parts of the power grid

ARP Spoofing

- Targeted denial of service
- Interrupt RTU connections
- Loss of visibility
- Loss of controllability

False Data Injection

- MitM-based attack
- Measurements manipulation
- Command injection
- Live and transparent

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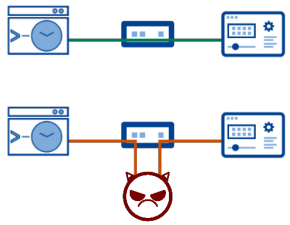
False Data Injection Attack: Scenario

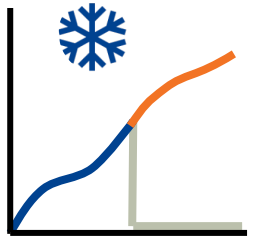
Attack Phases



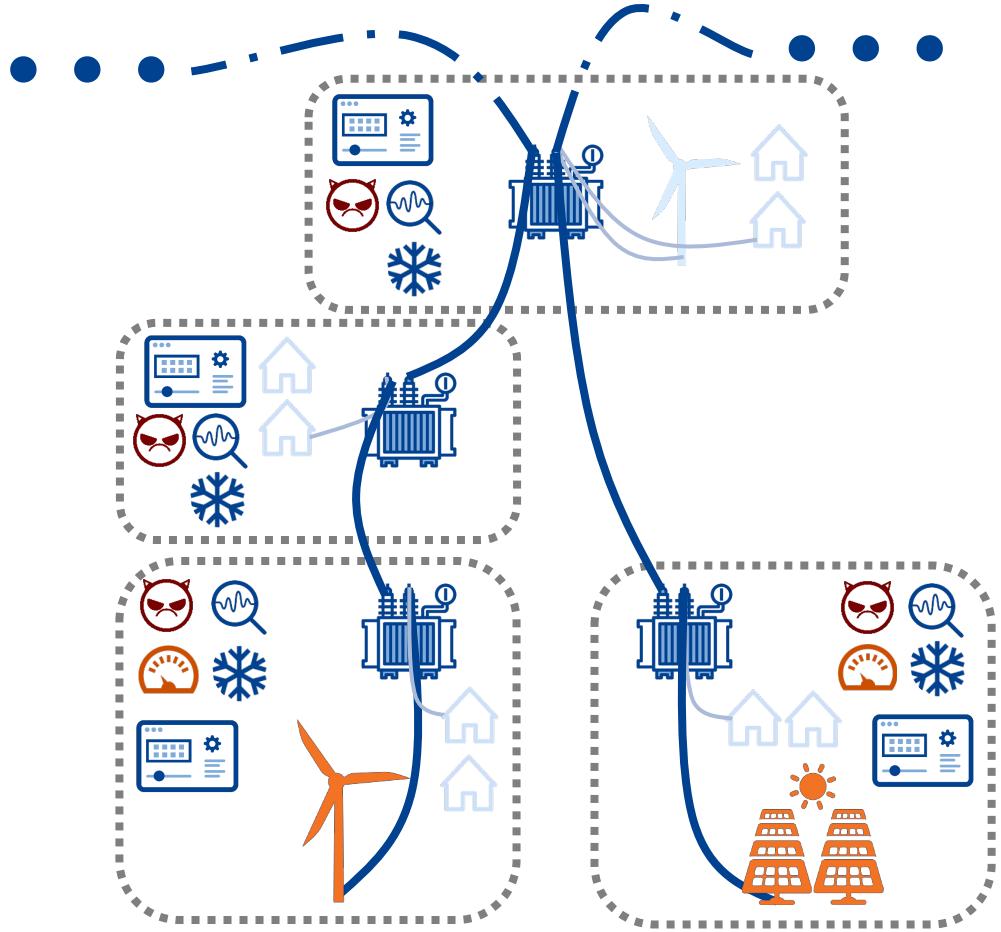
- MitM via ARP spoof
  - Learn SEQ/ACK (TCP) and SSN/RSN (IEC 104)

- Eavesdropping & recording
  - Learn measurement values & store history

- Command Injection
  - Inject control commands into active connection



- Freezing
  - Manipulate measurements to represent former grid state



Simbench semi-urban medium-voltage scenario
~ 110 substations, 119 RTUs
Represents a district

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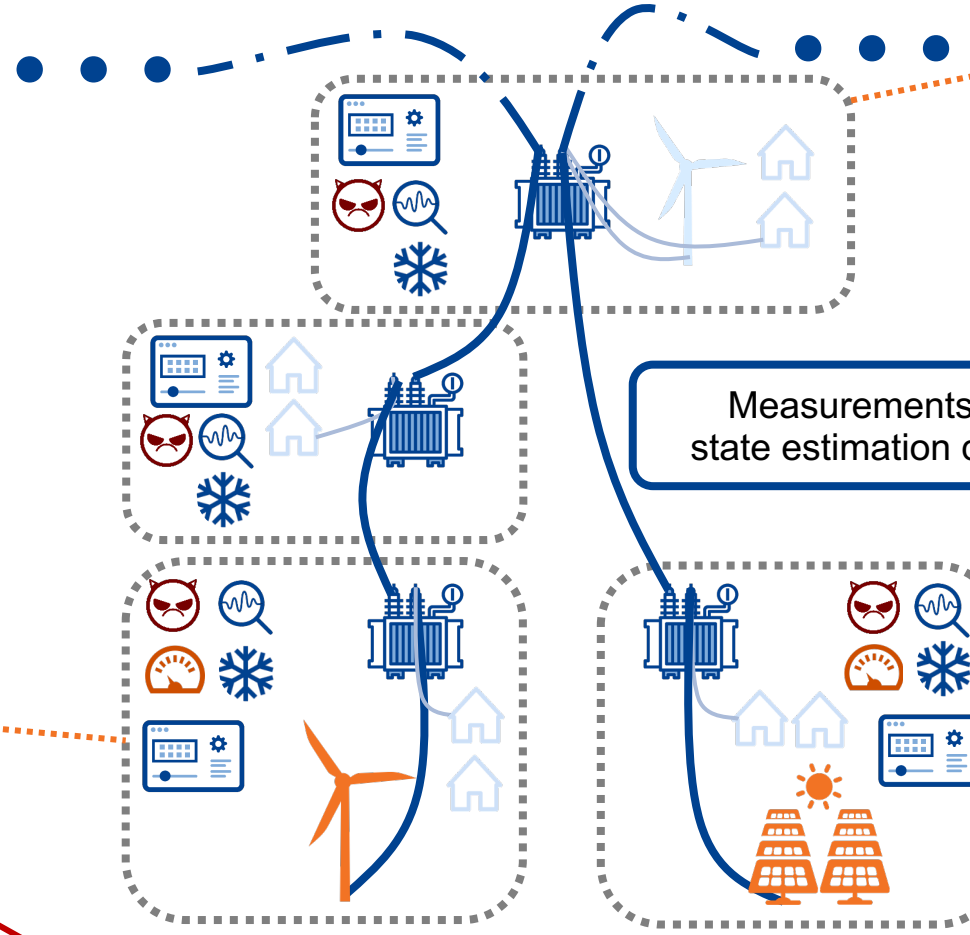
False Data Injection Attack: Evaluation

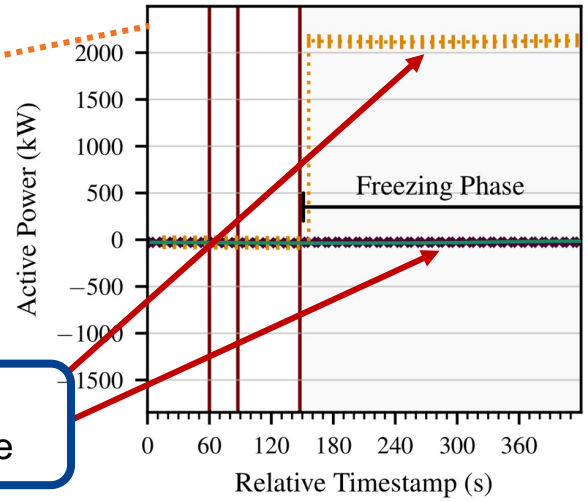
Loss of visibility

Loss of control

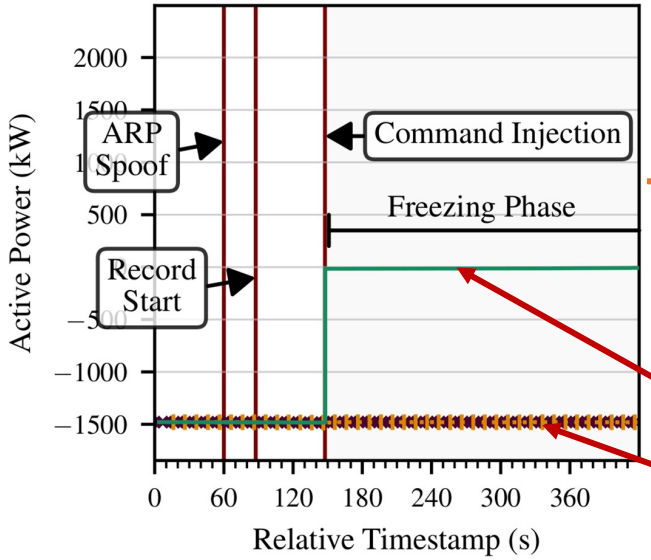
Incorrect conclusions

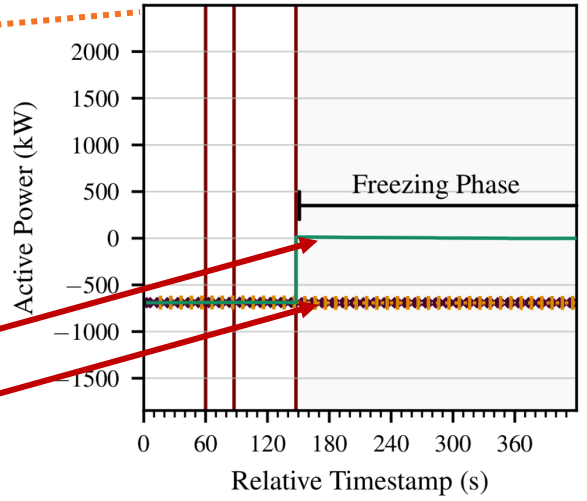
Impaired grid operation





Measurements and state estimation diverge





Measurements and state estimation diverge from actual grid state

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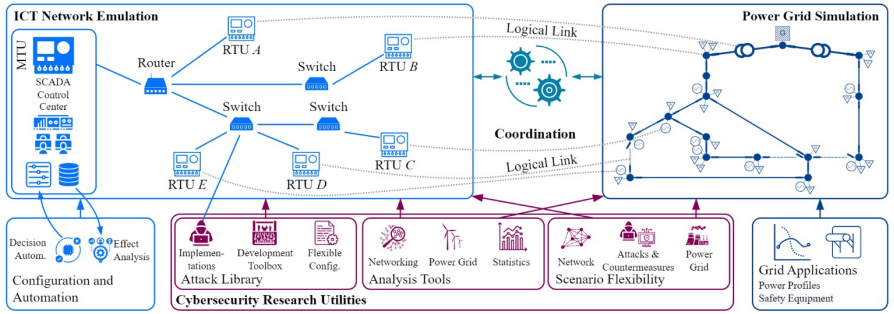
Conclusion

- **Power grids as targets for cyberattacks**
  - Digitized cyber physical system and critical infrastructure
- **Evaluation of attacks and their effects**
  - Co-simulation framework
  - Cybersecurity research focus
  - Evaluated attacks highlight potential vulnerabilities
- **Various applications for Wattson**

WATTSON



Evaluate intrusion detection systems	Analyze preventive countermeasures	Network forensics for energy networks
Attack evaluations	Awareness trainings	Dataset generation

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Thank you!

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