CREDC

Towards Attack Resilient Data Analytics for Power Grid Operations

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GPS SPOOFING ATTACKS ON POWER SYSTEMS

GPS Spoofing alters the phasor timing making it appear as if a substation's phase angle is inconsistent

- Current GPS clocks do not have a way of authenticating GPS signals
- Rely on a 1 pulse per second signal for timing
- Broadcasting a new pulse stronger than actual GPS allows attackers to change time

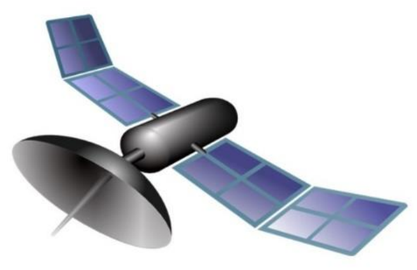
GPS Spoofing attacks on Phasor Measurement Unit (PMU)

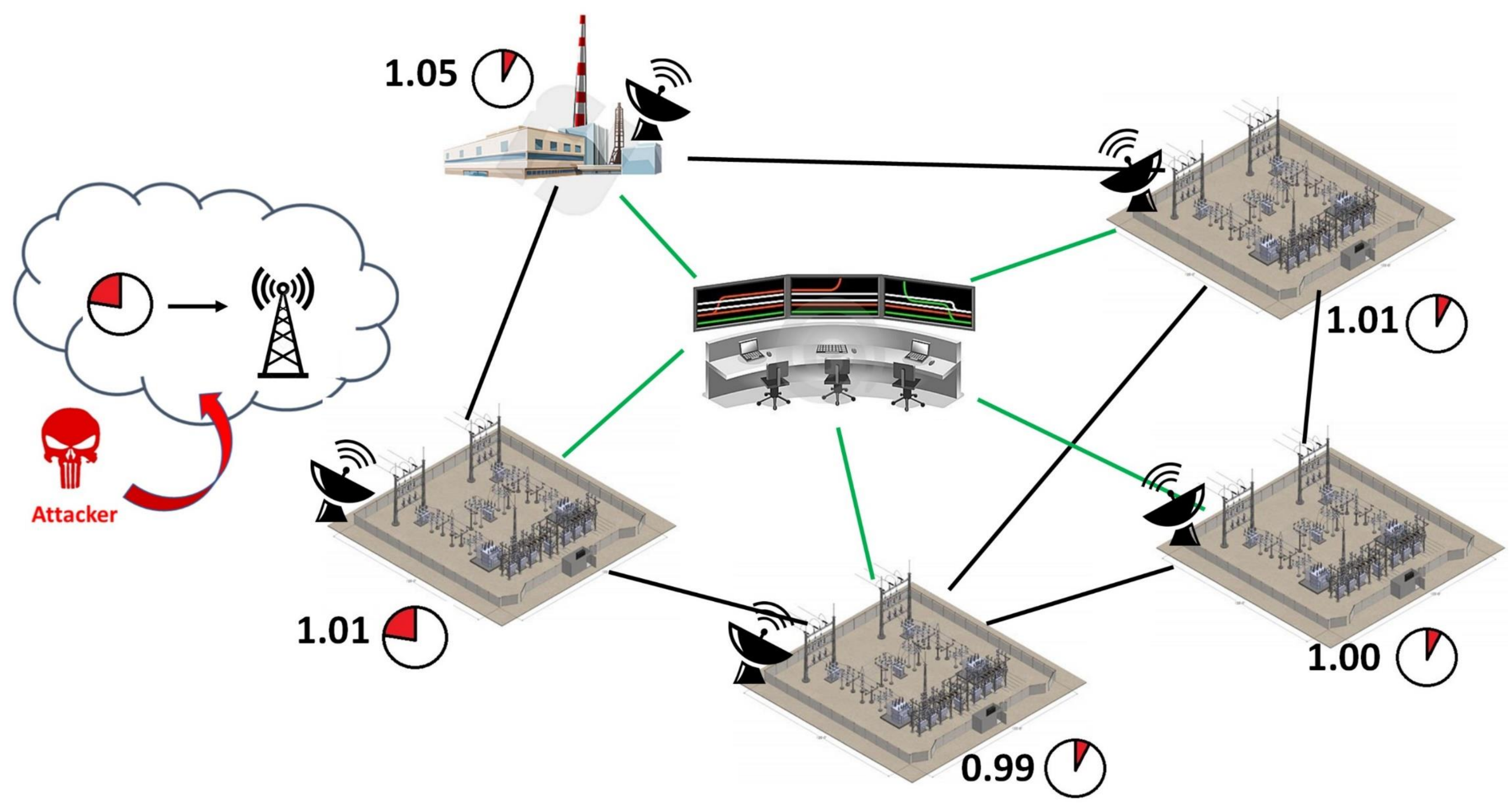
- PMU's measure voltage and current phasors at a substation
- Alter the reference time for phase angle estimation
- Introduce bias to phase angle measurements from attacked PMUs

GPS Spoofing is a comparatively easy attack to carryout

- Minimal required equipment
- Can be a few miles from substation
- Cost of components is less than $2000

How does this affect power grid control and protection, especially, smart algorithms?

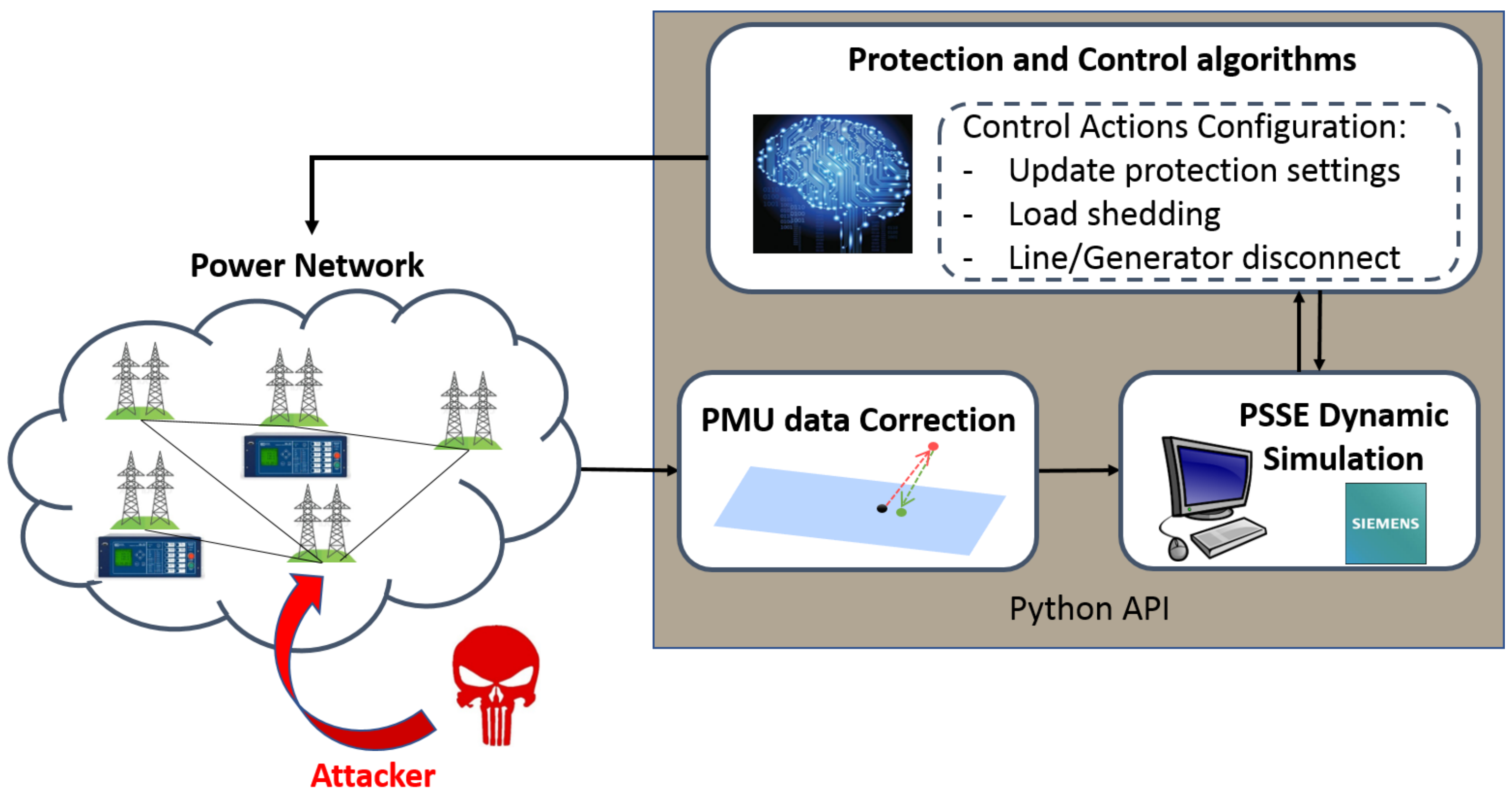




RESEARCH VISION

Develop attack-resilient data analytics for power system control and protection (that can isolate faults, mitigate damage, and recover lost components) in the presence of on-going GPS spoofing attacks.

OVERVIEW OF APPROACH


Protection and Control algorithms
Control Actions Configuration:
- Update protection settings
- Load shedding
- Line/Generator disconnect
Power Network
PMU data Correction
PSSE Dynamic Simulation
SIEMENS
Python API
Attacker

- PSSE handles the Dynamic Power System Simulation with standard Protection Devices (Distance, Overcurrent, Frequency trip, etc.)
- The Protection Control Module uses PMU data and simulation results to determine necessary protective and control actions
  - Best fit load shedding limits outage size
  - Determining protection settings in real-time makes the system more resilient reducing unnecessary line or generator disconnects
- The system requires accurate PMU data to avoid incorrect actions in the control systems
  - This is achieved through a Data Correction Module, which recovers PMU data that has been spoofed

PMU DATA CORRECTION

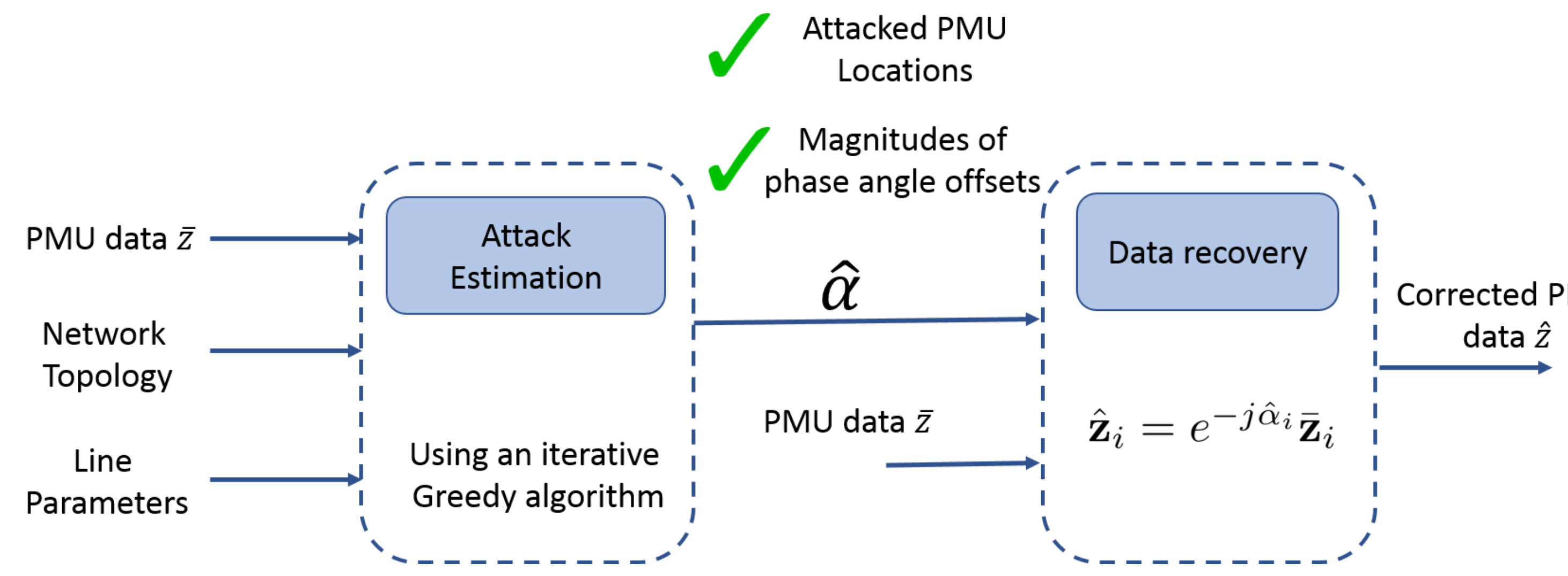
A feature of GPS spoofing attacks is that all the phasor measurements collected from *an* attacked PMU will have the same phase angle offset

- Effect of the attack on the i^{th} PMU : $\bar{\mathbf{z}}_i = e^{j\alpha_i}\mathbf{z}_i$

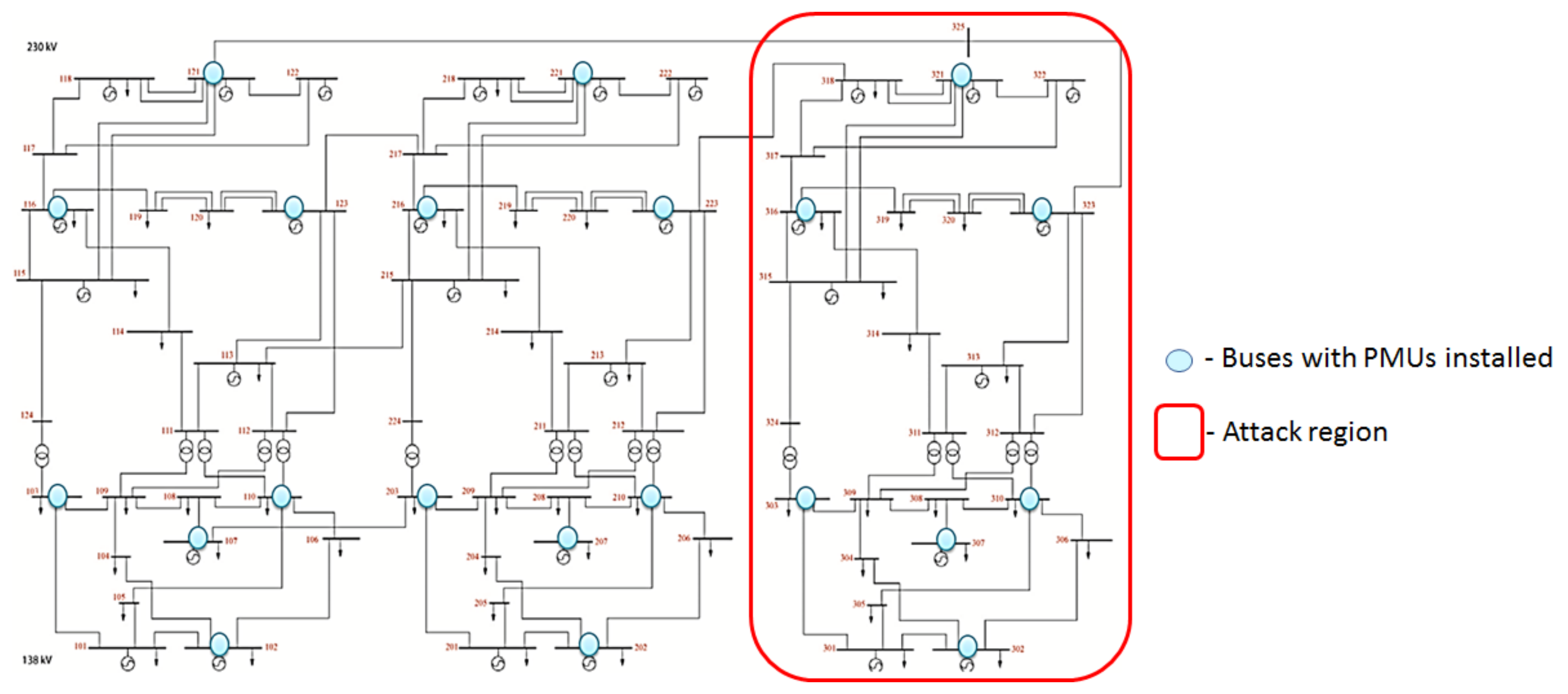
  $\mathbf{z}_i$ - Authentic PMU measurements from bus i

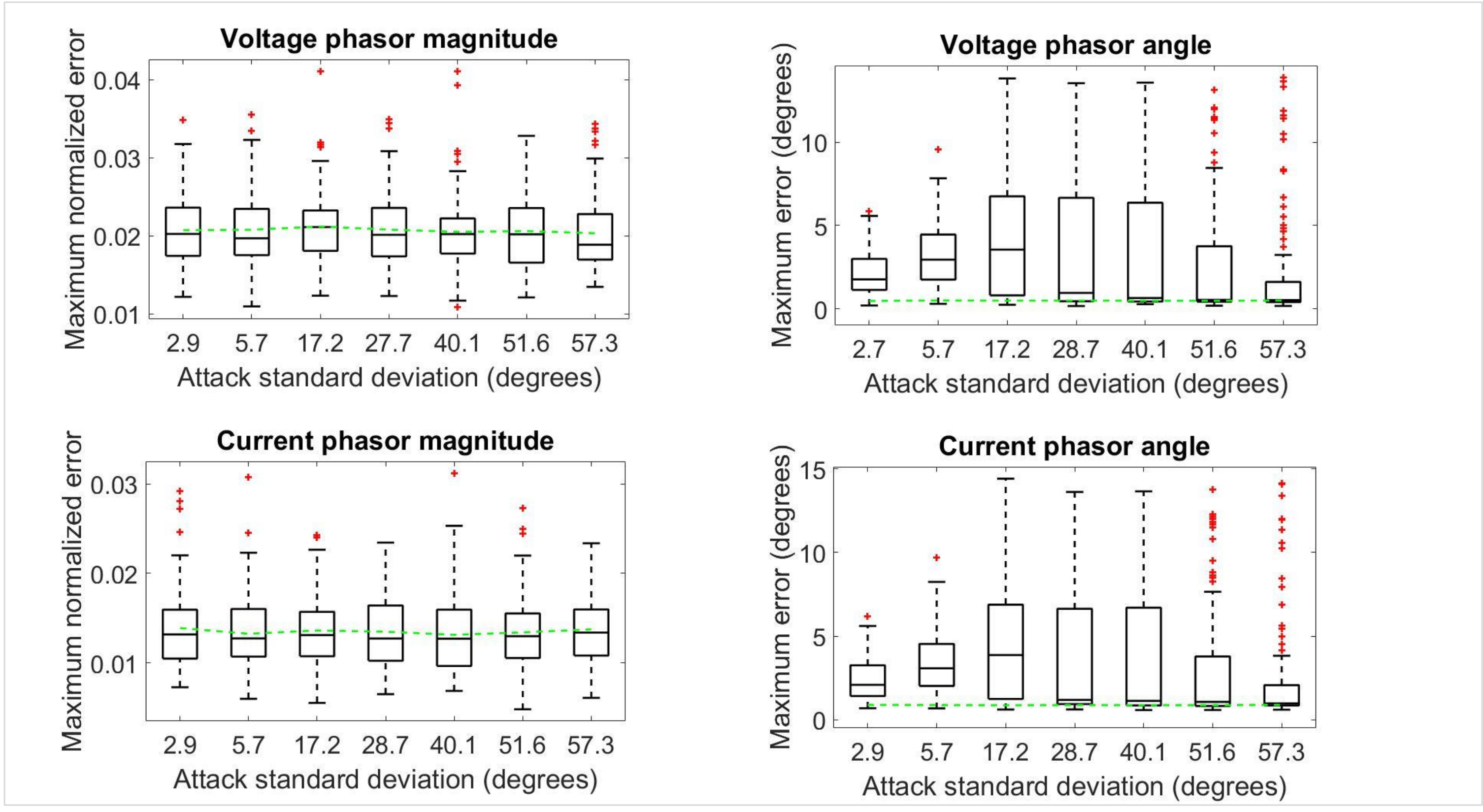
  α_i - Phase angle offset in bus i

  $\bar{\mathbf{z}}_i$ - Spoofed PMU measurements from bus i
- $\boldsymbol{\alpha} = [\alpha_1; \alpha_2; \ldots; \alpha_K]$: the angle offsets at all *K* PMUs induced by spoofing attack. Usually a small subset of PMUs are compromised, thus mo$\boldsymbol{\alpha}$ entries of are z$\boldsymbol{\alpha}$ 'o, i.e., is a sparse vector.
- We employ an iterative sparse optimization algorithm that leverages the knowledge of network topology and line parameters, to estimate the attack $\boldsymbol{\alpha}$ ctor and correct PMU measurements.


✓ Attacked PMU Locations
✓ Magnitudes of phase angle offsets
PMU data $\bar{z}$
Network Topology
Line Parameters
Attack Estimation
Using an iterative Greedy algorithm
$\hat{\alpha}$
PMU data $\bar{z}$
Data recovery
$\hat{\mathbf{z}}_i = e^{-j\hat{\alpha}_i}\bar{\mathbf{z}}_i$
Corrected PMU data $\hat{z}$

RESULTS ON RTS-96 TEST CASE





IMPACT ON POWER GRID

Employing our attack-resilient data analytics, your system can:

- Effectively mitigate GPS spoofing attacks on PMU measurements
- Avoid having attacked PMU data affect control decisions
- Make use of PMU data for real time control & protection in a secure way

COLLABORATION OPPORTUNITIES

Cooperation, support and guidance from industry partners in the following areas would benefit this research activity:

- Specifications or methods for coordinating real protection systems
- Alternative uses of phase angle in automated or semi-automated control systems
- Methods to evaluate power system protection performance and hardware validation

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Activity webpage: https://cred-c.org/researchactivity/Analytics4GridOps

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FUNDING SUPPORT PROVIDED BY THE U.S. DEPARTMENT OF ENERGY AND THE U.S. DEPARTMENT OF HOMELAND SECURITY