Key Insights and Future Research Directions

Review of Results

- Reinforcement learning agents trained for IEEE 13, 37, 123, 8500 node systems, Iowa 240 (representative of co-op circuits)
  - Utilized synthetic load and solar generation
- Variety of different attack scenarios explored
  - Attacks considered: oscillations, voltage imbalances
  - Varying attack severities: 10% - 50% of feeder solar photovoltaic systems compromised
- Reinforcement learning agents integrated into NRECA OMF
  - Pre-trained agents populated for default feeders
  - Training customized agents is enabled (but it takes some time)

Key Insights

- RL agents perform well in mitigating the effect of attacks on solar PV systems when the percentage of attacked inverter capacity is less than 50%
  - For larger radial feeders (IEEE 8500) smaller cyber attacks (e.g., 20% attacked inverter capacity) are pronounced compared to smaller feeders
  - Smaller attacks on specific sections of a feeder can cause local imbalances/oscillations
  - Adjusting non-compromised solar inverters in these specific regions would also be effective in mitigating the effect of the attacks
- RL agents can be trained to mitigate multiple type of attacks simultaneously (e.g, can mitigate attacks to create oscillations and imbalances)
- RL agents can learn to utilize presence of other dynamics in the system as part of their defensive strategy

Project Footprint

- Papers:
  - C. Roberts, S. Ngo, A. Milesi, A. Scaglione, S. Peisert, and D. Arnold, “Deep Reinforcement Learning for Mitigating Cyber-Physical DER Voltage Unbalance Attacks", American Control Conference (ACC), 2021, accepted.
  - C. Roberts, S. Ngo, A. Milesi, S. Peisert, S. Saha, A Scaglione., N. Johnson, A. Kocheturov, D. Fradkin, and D. Arnold “Deep Reinforcement Learning for DER Cyberattack Mitigation", IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm), Tempe, AZ, USA, 2021.
  - S. Saha. D. Arnold, A. Scaglione, E. Schweitzer, C. Roberts, S. Peisert, and N. Johnson, “Lyapunov Stability of Smart Inverters Using Linearized DistFlow Approximation”, IET Renewable Power Generation, vol. 15, no. 1, pp. 114-126, 2021.
  - I. Losada Carreño, R. Ramakrishna, A. Scaglione, D. Arnold, C. Roberts, S. Ngo, S., D. Pinney, “SoDa: An Irradiance-Based Synthetic Solar Data Generation Tool”, IEEE International Conference on Communications, Control, and Computing Technologies for Smart Grids (SmartGridComm), Tempe, AZ, USA, 2021.

Project Footprint

- Graduate Students Supported:
  - Shammya Saha (ASU):
    - Supervisors: Nathan Johnson & Anna Scaglione
    - Expected graduation date: June 2021
  - Ignacio Losada Carreño (ASU):
    - Supervisor: Anna Scaglione
    - Expected graduation date: Summer 2022
  - Ciaran Roberts (UC Berkeley):
    - Supervisor: Duncan Callaway
    - Expected graduation date: June 2022

Future Research

- CIGAR project scratches the surface of the use of AI techniques for real-time electric grid cybersecurity
- Promising research directions:
  - Extending scope to consider other types of controllable devices (battery storage & EV/EVSE)
  - Application of GCN to train a single agent that is insensitive to network topology
  - Integration of reinf. learning algorithms into ADMS/DERMS or directly into inverter
  - Extending scope to include IT communications
  - Extending scope into other domains: buildings, transportation, natural gas distribution
    - HELICS synergies

Reinforcement Learning Training Loop

Agent
(Proximal Policy Optimization - PPO)

states & rewards

actions

Environment

OpenDSS

- PV with smart inverter functions (Volt-VAR/Volt-Watt) - CIGAR
- Battery Storage - SPADES
- EV/EV charging - TBD

Voltage and power flow timeseries & attack mitigated?

e.g. PV and battery setpoints

Supervisory Parameter Adjustment for Distribution Energy Storage - SPADES

Performers:

Lead Institution

Project Details:

- **Total Value of Award:** $3,209,749
  - $3,000,000 DOE share
- **Sponsor:** Cybersecurity for Energy Delivery Systems (CEDS) program, CESER Office
- **Period of performance:** 01/01/20 - 12/31/2022
- **Goal:** Develop artificial intelligence to defend energy storage systems and the electric grid against cyber attacks on both the grid and storage devices themselves

Supervisory Parameter Adjustment for Distribution Energy Storage - SPADES

Performers:

Lead Institution

Roles and Tasks:

- **LBNL:** Project management, feedback control modeling, AI algorithm development, software design, OMF integration
- **Siemens:** Red team
- **ASU:** Grid modeling, software design
- **NRECA:** OMF integration
- **Project Tasks:**
  - Task 1: Feedback control modeling
  - Task 2: Algorithm development
  - Task 3: Red team experiments
  - Task 4: OMF

Thank you!

Thanks to all CIGAR team members

and our sponsors at CEDS!

Questions/Discussion

Backup Slides