

Optimization and Machine Learning Applications in Power Grids

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Researcher on Power Systems and Protection

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- Present grid edge energy management system (GEEMS) considers to schedule distributed energy resources (DER) to minimize overall electricity purchase cost from grid
- It doesn't consider whether schedules of DERs are going to cause IEEE 1547 standard violation
- As a result, circuit segments may face situations like mandatory cessation from grid
- DERs in a circuit segment should be scheduled to comply with IEEE 1547 standard and maximize the economic benefit.
- This work includes constraints while scheduling DERs to avoid IEEE 1547 standard violation in a circuit segment



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Optimization Problem Formulation

$$J = \min \{C_{gd}P_{gd} + \sum_{dg=1}^{n_{dg}} P_{dg}C_{dg} + \sum_{es=1}^{n_{es}} W_{es} P_{es}\}$$

Subject to :

Equality constraints:

Power Balance : Input and output power should be equivalent

Charge Balance of Energy Storage

Inequality constraints:

Constraints for DG ramp up and ramp down, active and reactive capacity

Constraints for ES charging/discharging capacity

Constraints for SOC

Constraints for PV active and reactive power capacity

Constraints for node voltages



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GEEMS Demo Lab Implementation – DER Interactions



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Case Study

Modified Rankin Feeder model from Duke Energy.

1 diesel generator (DG) – 2 MW

- 1 battery energy storage (BES) 0.5 MW
- 1 PV generator- 10 MW

Aggregated 12 loads - 13.3 MW

Without violation constraint consideration on GEEMS



Violation constraint consideration on GEEMS



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- The real-time simulation shown in this work demonstrates significant performance of grid code compliant grid edge EMS by reducing the voltage violation on the overall circuit segment.
- Deployment of IEC 61850-7-420 DER information models and GOOSE communication protocol in real-time simulation portrays the benefits for utilization of advanced communication standards and protocol in EMS.
- Overall, the grid edge EMS method and deployment of IEC 61850-7-420 DER on real-time implementation shows the reliability enhancement on grid edge technology.





- □ Instant load measurement are utilized to control DERs GEEMS.
- □ This triggers the possibility of malicious attacks from adversaries that will affect the control functions of GEEMS.
- Existing bad data detection algorithms is performed to avoid such situation.
- Unobservable false data injection (FDI) may bypass this traditional algorithm.
- We proposed a new enhanced anomaly detection and prevention algorithm to overcome the impact of unobservable attack in GEEMS.

Proposed Method



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Case Study



- Load values are increased on three nodes through FDI in IEEE
 13 bus system
- □ Residual based detection failed to detect FDI.
- Though no voltage violation is expected with the operation of network constrained grid edge EMS, voltage violations at multiple buses occur during some intervals in real system if FDIAs remain present.
- On the other hand, if network constrained grid edge EMS is performed following the proposed two-step detection and load replacement algorithm, then zero violation is faced for the over all time in real system.





Largest normal residues after attack is below threshold



Load measurement change through cyber-attack at 32nd interval



Total number of violated buses with attack and replaced attacked load

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- This work proposes a framework to enhance the resilient operation of grid edge EMS by detecting the unobservable FDIAs on loads and replacing them with forecasted values.
- □ A two-step detection algorithm is presented to detect unobservable FDIAs in this regard.
- After ensuring the presence of FDIAs, the location of FDIAs is detected and replaced with forecasted load values following LSTM in this method.
- Simulation results demonstrate that the proposed framework avoids the grid code violation and enhance security for grid edge EMS.
- This proposed method will assist centralized controlled circuit segment or microgrid owners to avoid violation in system when measurements are tempered by the adversaries.





- □ F. Hafiz, D. Ishchenko, P. Almaleck, "Network constraints consideration for grid-edge energy management system", 2022 IEEE/PES *Transmission and Distribution Conference and Exposition (T&D)*, New Orleans, LA, USA, Apr. 2022.
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- F. Hafiz and D. Ishchenko, "Security Enhancement of Network Constraint Grid-Edge Energy Management System", 2022 IEEE Industry Applications Society Annual Meeting (IAS), Detroit, MI, USA, Oct, 2022.



