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ASSESSING THE RELIABILITY CONTRIBUTIONS OF ENERGY STORAGE AS A TRANSMISSION ASSET

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PROJECT OVERVIEW

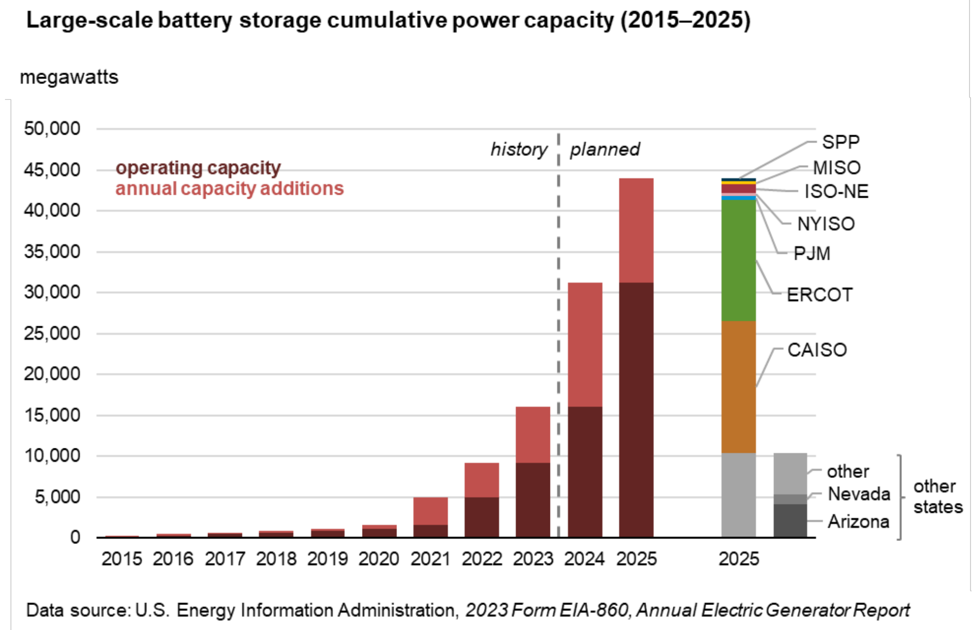
- **Project Goal:** Provide decision support and analytical solutions for energy storage as a transmission asset.
- **Current Practices:**
  - FERC guidance: Encouraging competition and advanced transmission technologies
  - RTO/ISO tariffs: ISONE, MISO, SPP, etc.
  - Existing (or ongoing) projects: e.g., Waupaca Area Storage/MISO: 2.5MW/5MWh
- **Why ANL (Lab progress/capability):**
  - ANL's capabilities:
    - Energy storage system and component modeling
    - Grid modeling and analysis: Transmission, distribution, planning and operations, reliability and resource adequacy analysis
- **Innovation and Impact:**
  - First-of-its-kind tool that systematically assesses the reliability contributions of SATA. It benefits both asset owners and ISO/RTOs by improving decision-making around ES investments and operations as a SATA.
  - By representing unique operational characteristics, the project will set a precedent for operational protocols that can be adopted across different RTOs, aligning ES operations with established transmission planning and reliability standards. These rules will not only improve the immediate effectiveness of SATA deployments but also contribute to the long-term development of industry standards for SATA.
- **Vertical/Investment Area:**
  - *Analytics and Grid Integration and Field Validation*: provide decision and analytical support tool for storage operator/investors and RTOs to consider storage as a transmission solution.
- **Alignment/Supports strategic pathway:**
  - Explore new use case for energy storage by assessing its feasibility and economic viability.
  - Provide alternative solutions to conventional-line based transmission solution, to improve system reliability, cost efficiency during the transition to support large and emerging load.

PROJECT OVERVIEW

- **Project Timeline and Budget**
  - 24 months (FY25Q2 – FY27Q1)
  - $200k/year
- **FY26 Research Progress and Activities**
  - SATA physical and operational representation in grid reliability assessment model
  - Grid reliability assessment model upgrade with (1) line outage sampling; (2) Multiple steps re-dispatch after contingences
  - Case study based on ERCOT county-level grid representation

PROJECT DETAILS: PROBLEM

- **Motivation**
  - Energy storage has seen significant growth in power systems in the last decade.
  - However, its deployment for transmission application remains relatively limited.
    - Primary applications served by large-scale storage are energy arbitrage, frequency regulation, absorbing variable generation, and system peak shaving*.



* U.S. Energy Information Administration, 2023 Form EIA-860, Annual Electric Generator Report

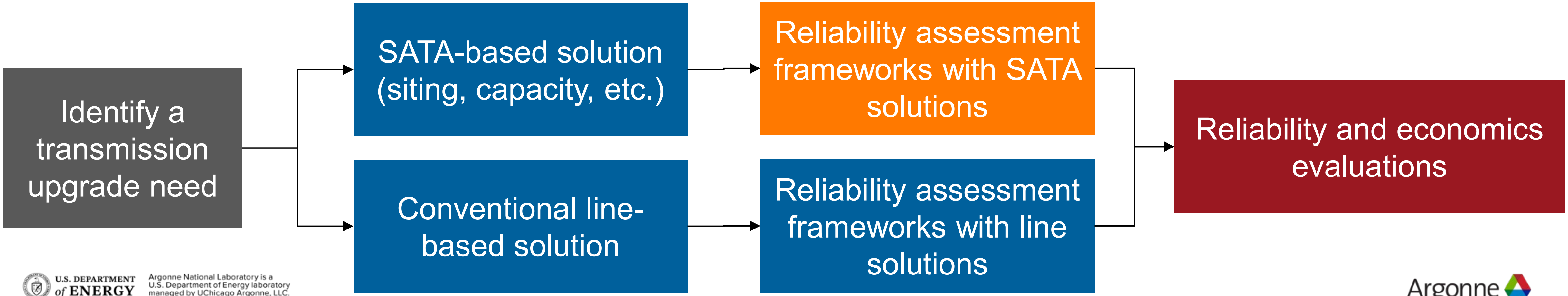
PROJECT DETAILS: PROBLEM

Storage as transmission assets

- Role of storage:
  - Storage to replace transmission: storage may defer transmission investment by mitigate congestion, no need to be as transmission asset to achieve this.
  - Storage as transmission asset: storage is part of transmission planning process, can only serve transmission services primarily at specific operational conditions.
- Transmission services that energy storage can provide as transmission asset
  - Real power based: injecting or withdrawing real power to/from the grid, addressing e.g., thermal overloading.
  - Reactive power based: provide reactive power, addressing e.g., voltage violation.

PROJECT DETAILS: PROBLEM

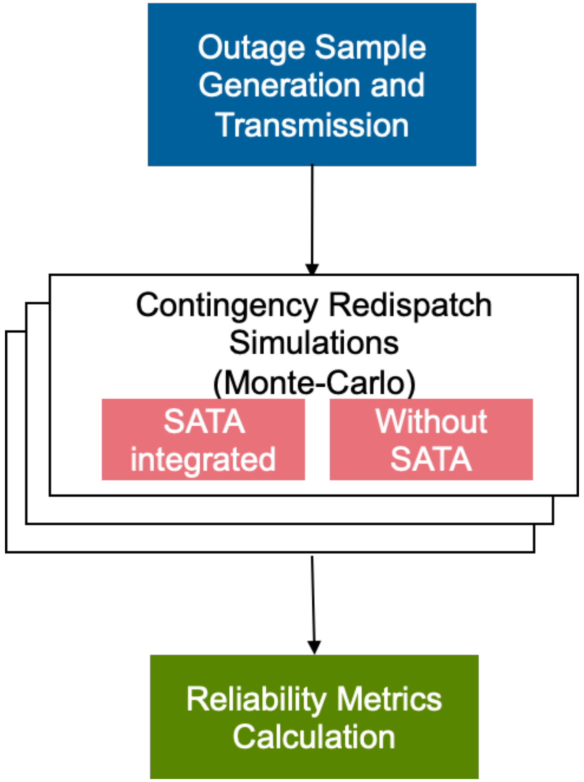
- **Research questions**
  - As a transmission asset, how to assess the reliability contribution of an energy storage project, to make it comparable with a conventional line-based transmission solution to address the same transmission upgrade need?
    - Storage locations, capacities, durations….
    - Operational constraints: SATA can be called to provide services only when all market solutions are failed in contingencies. In practice, a SATA asset is dispatched only in a N-1-1 contingency, such as in MISO and ISONE.
    - Reliability assessment frameworks
    - Critical component in transmission planning, capacity adequacy study and capacity accreditation
  - Assessment workflow



PROJECT DETAILS: APPROACH

Probabilistic Reliability Assessment (RA) Model implemented on A-LEAF, an inhouse grid modeling framework

- May purpose of RA study: Evaluate system reliability under various (peak) operational conditions and uncertainties with selected metrics and target. In practice, the grid reliability is measured by loss of load expectation (LoLE), and the industry standard is 1 day in 10 years.

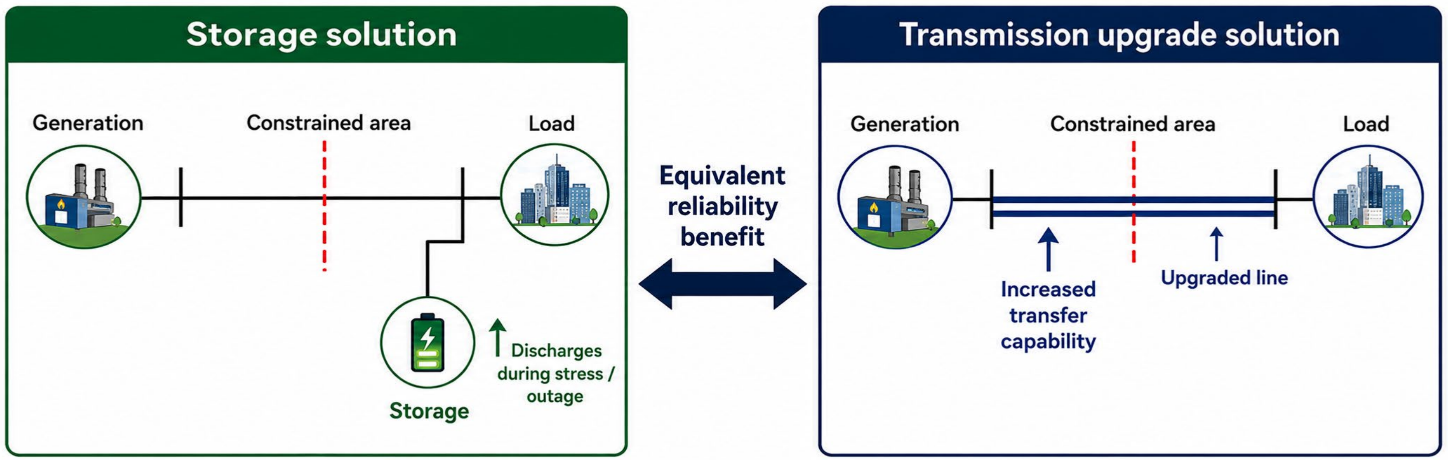


- Temperature-dependent generator and line outage sampling that utilizes a Markov chain approach to model state transitions
  - Sampled hourly over a full year
- Efficient sample filtering method to reduce the number of risk samples requiring dispatch simulations while maintaining the accuracy of resulting reliability metrics
- Two-stage system dispatch simulations with and without perfect foresight
  - First stage: Steady-state system operations
  - Second stage: Realization of system risks and post-contingency system redispatch
- Determines a range of metrics to evaluate system performance.
  - EUE, NEUE, LOLH, LOLP, and LOLE.
  - Indicators of outage severity (e.g., the maximum consecutive hours with load shedding, and the maximum load-shedding capacity in MW and MWh).

RELIABILITY ACCOUNTING/MARGINAL RELIABILITY METRIC

- **Reliability metrics**
  - Total expected unserved energy(EUE)
  - Marginal EUE contribution
    - EUE reduction per capacity increase of storage capacity or transmission line at various grid conditions

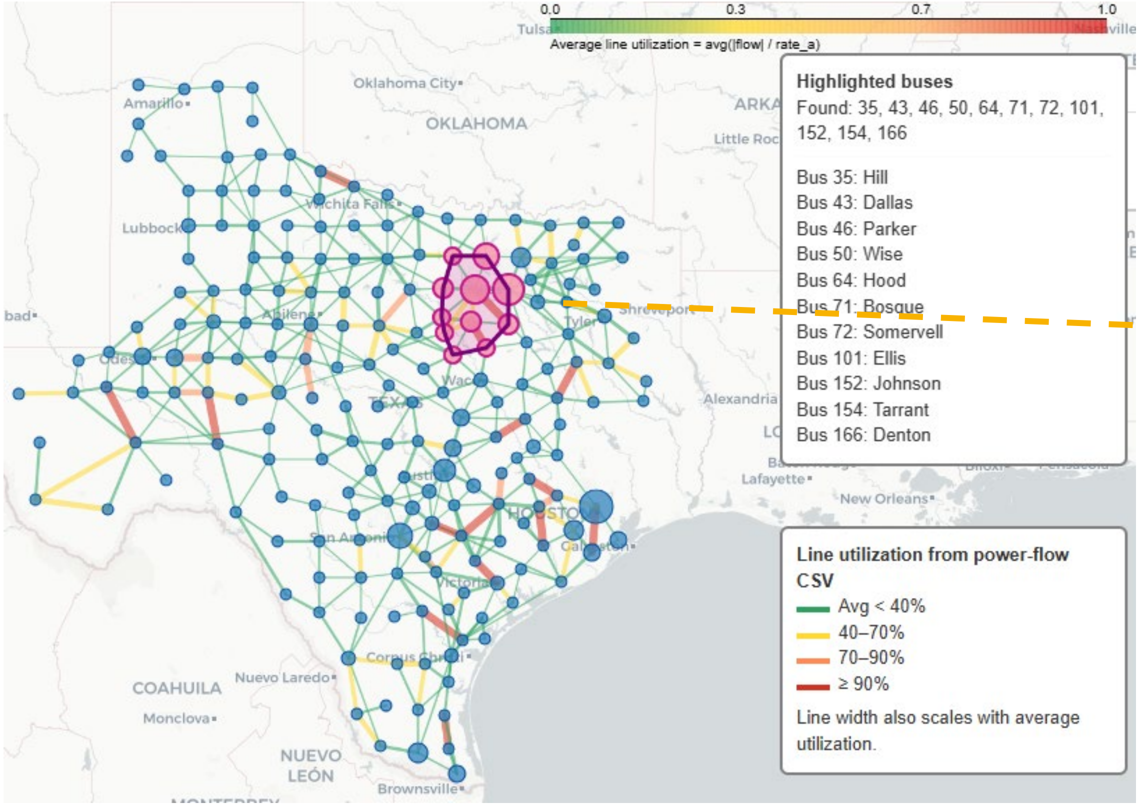
- **Equivalent solutions of SATA and transmission line upgrade**
  - Achieving the same EUE results of the targeted region

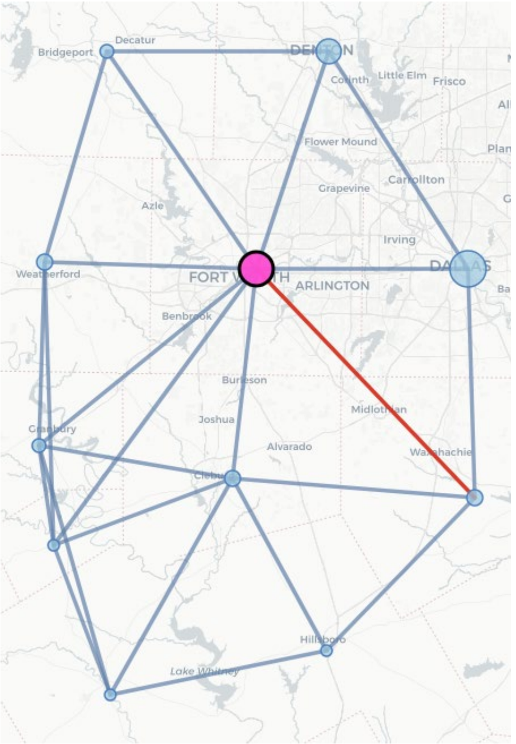


PROJECT DETAILS: RESULTS

Testing system

- Texas ERCOT county system
- Evaluate the regional area of the whole system

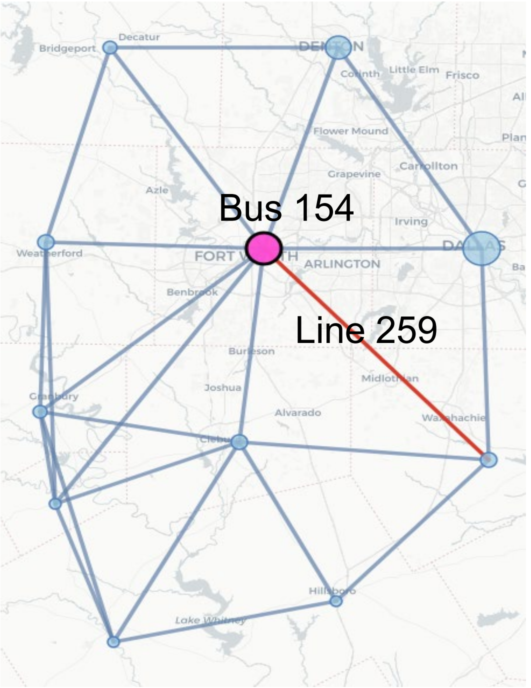




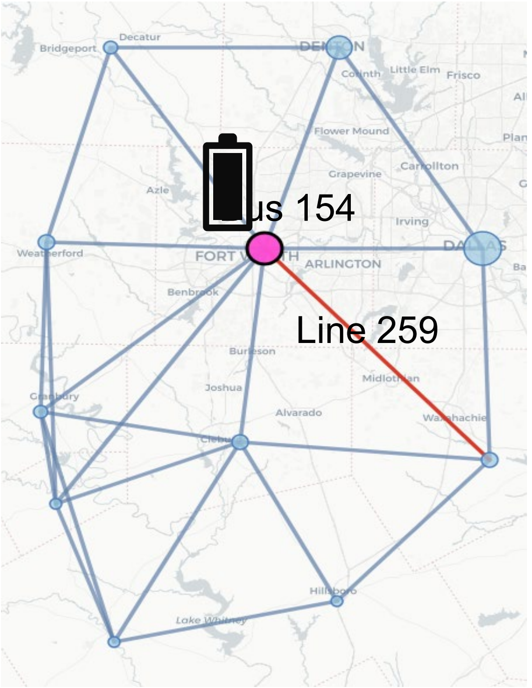
PROJECT DETAILS: RESULTS

Testing system

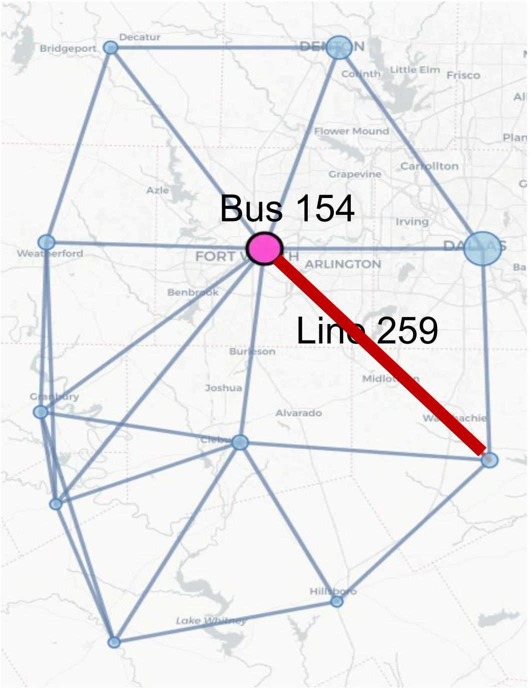
- One representative day and 100,000 samples
- Line upgrade candidate: Line 259; always congested over 24 hours
- SATA bus candidate: Bus 154; with the highest EUE



Base



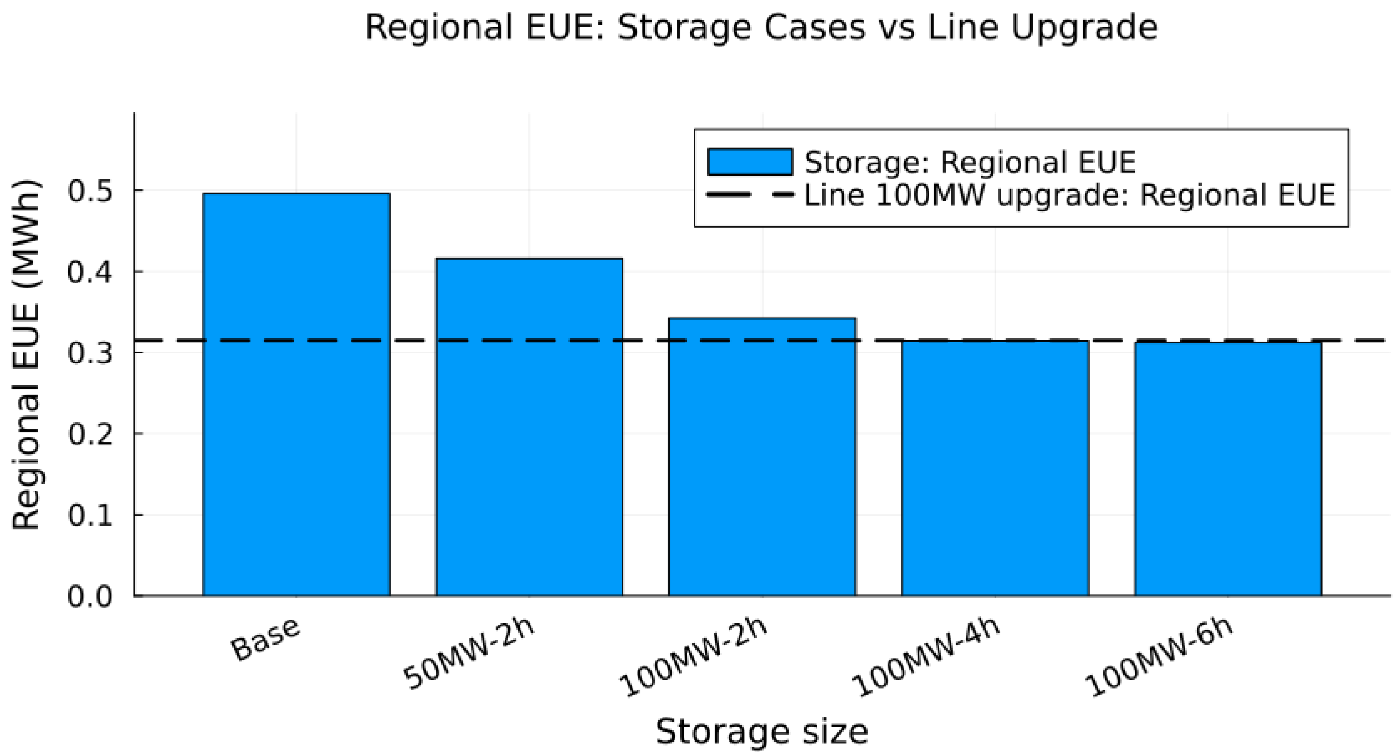
SATA solution



Line upgrade solution

PROJECT DETAILS: RESULTS

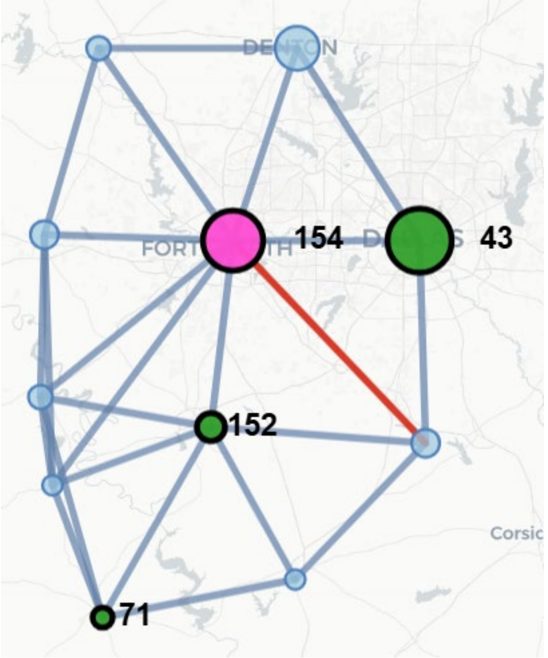
Equivalent SATA solution to line upgrade

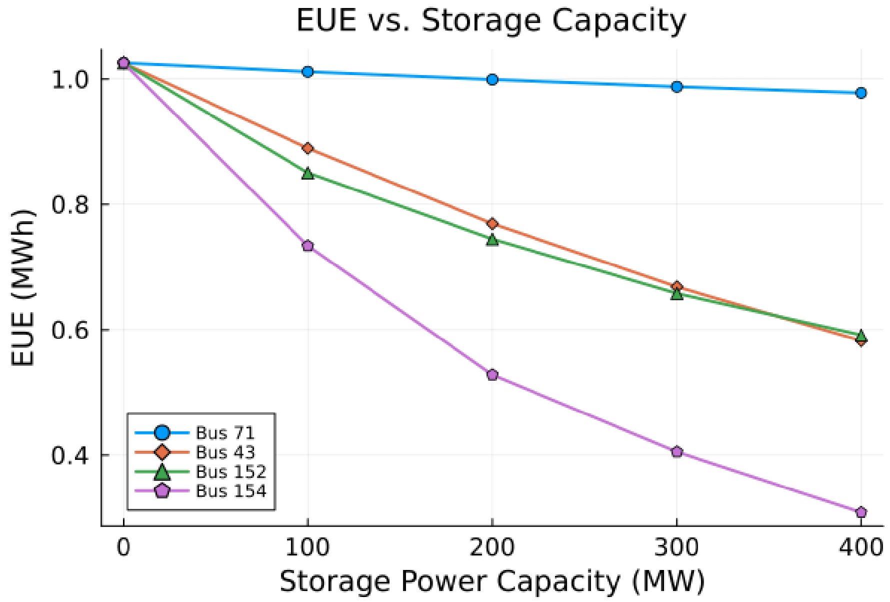


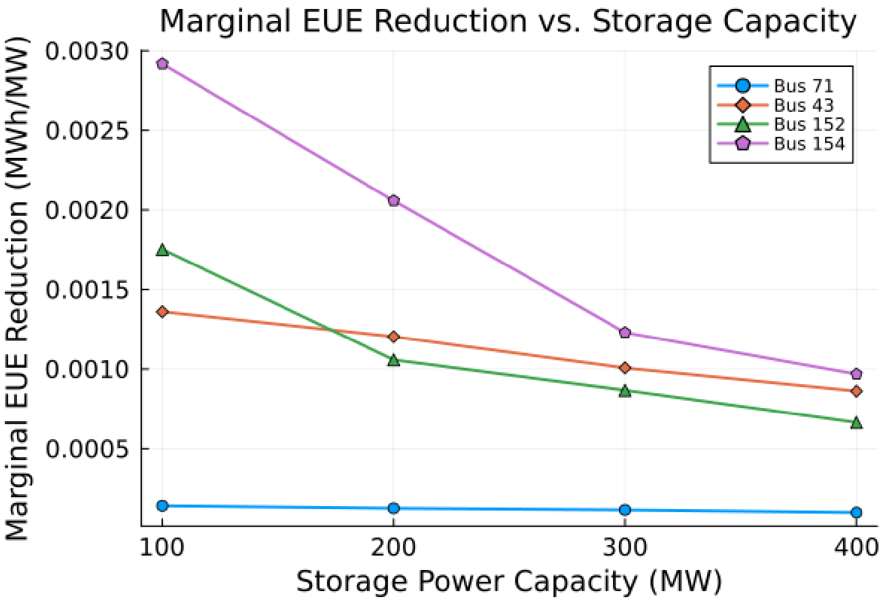
- 100MW-4h storage can achieve equivalent EUE results to the 100MW line upgrade solution.
  - 100MW-4h Li-ion battery sees a higher cost ($10.3 million/year) than the line solution ($2.4 million/year) if the storage serves as the transmission asset only.
- Longer storage duration reduces EUE from 2h to 4h, but benefits beyond 4h are limited due to outage-duration constraints.

PROJECT DETAILS: RESULTS

Locations of SATA







- The placement locations of SATA can significantly impact the reliability results.
- Bus 71 is not directly connected to Bus 154. Little reliability contributions is observed if SATA is located at Bus 71.

PROJECT DETAILS: CONCLUSION

- Conclusion
  - The project reviews the role and operational constraints of SATA and develops representation models of SATA, which can be integrated to existing grid reliability assessment and planning models.
  - In Year 1, this work has developed a reliability assessment framework to evaluate SATOA's contributions towards system reliability and compare it with a transmission-line based solution regarding their reliability equivalence. Subsequent economic evaluation indicates that SATA is currently more costly than transmission-line upgrades under reliability equivalence. However, potential dual use, declining storage costs, and greater siting flexibility are expected to enhance the competitiveness of storage solutions.
  - This framework evaluates the concept of a locational marginal reliability contribution. Simulation results reveal strong heterogeneity in reliability contributions across locations and highlight the importance of explicitly considering the siting of SATA to enable proper cost savings and allocation.
- Future work
  - Dual-use: SATA is allowed for market participation during a period when system reliability is sufficient without it. This use case may improve the revenue of SATA, but may be at the cost of reliability loss or additional cost/degradation associated with market participation.
  - An integrated end-to-end decision support tool for RTOs and SATA operators/investors, which includes: (1) SATA reliability assessment; (2) SATA as a candidate solution in transmission expansion; (3) SATA operational decision support; (4) economic evaluation at project and system levels.

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