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Economic Threshold of Local Resilience in the Context of Constraint Transmission Line Capacity

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Abstract

- **Challenge:** Power systems must manage renewable variability and rising demand while being resilient to natural disasters, attacks, etc. This requires balancing local resilience versus reliance on the main grid
- **Local Resilience Solutions:** Recent research focuses on incorporating local resilience solutions, such as microgrids and Energy Storage Systems (ESS), to optimize the use of local renewables and meet demand with limited grid capacity
- **Research Gap:** There is a need to assess the conditions under which local resilience solutions become economically infeasible to guarantee reliability and should yield to grid expansion instead
- **Paper Objective:** This paper addresses the gap by delineating the boundary conditions up until local resilience solutions can increase power system reliability without the need for grid expansion
- **Methodology and Findings:** Using a multi-stage stochastic decision program and a case study, the paper illustrates the trade-off between reliance on the main grid and local resilience, identifying the economic threshold for prioritizing ESS deployment
- **Application:** In areas where demand exceeds local supply, this approach offers a pathway to improve resilience without immediate reliance on costly grid expansion

Model Methodology

- **Model Focus:** CBA model evaluating investment & operational costs of Energy Storage systems in a microgrid, incorporating sensitivity analysis for transmission capacity on main grid connection
- **Analysis:** Model assesses storage needs and optimal operation as well as day-ahead bidding to ensure a highly reliable microgrid, meeting inelastic demand
- **Multistage Optimization:** To determine the best strategy, the model predicts future weather and market conditions, employing Stochastic Dual Dynamic Programming (SDDP)
- **SDDP Approach:**
  - Follows Aaslid et al. (2021) methodology for realistic storage unit operation and bidding strategy with uncertain future parameters
  - This includes a long-term model (monthly updates for storage end value function) and a short-term model (six-hourly updates), integrated into a real-time simulation model
  - Utilizes past scenarios to optimize decisions under uncertain future prospects, enhancing results for forecasts

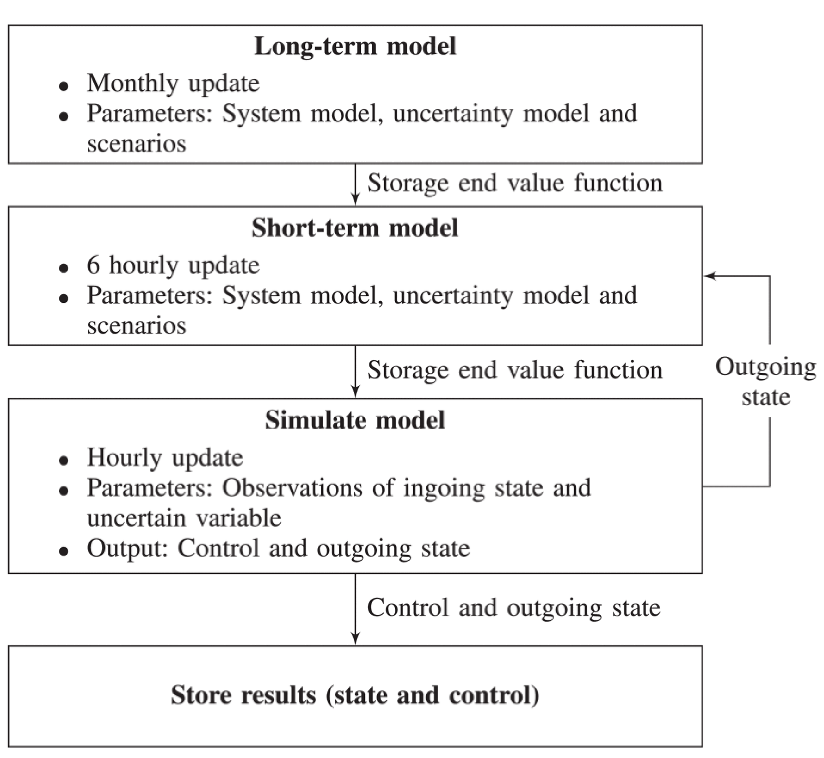

Figure 1: Model overview by Aaslid et al. (2021)[1]

- **Outcome:** Determines the need for local ESS to provide a reliable local power system under limited capacities to the main grid

Case Study

- **Novelty:** Study analyzes variation in investment & operational costs of ESS under different resilience requirements for the local system, addressing a current gap in research. It further assesses the differences in the value of add. transmission capacity using dual values of the varying line constraint
- **Setup:** Conceptual model of the Rye microgrid in Norway with one connection to the main grid, wind & solar generation, and ESS
- **Island Mode Assumption:** Microgrid switches instantly to islanded mode in event of upstream fault while voltage and frequency within are stable

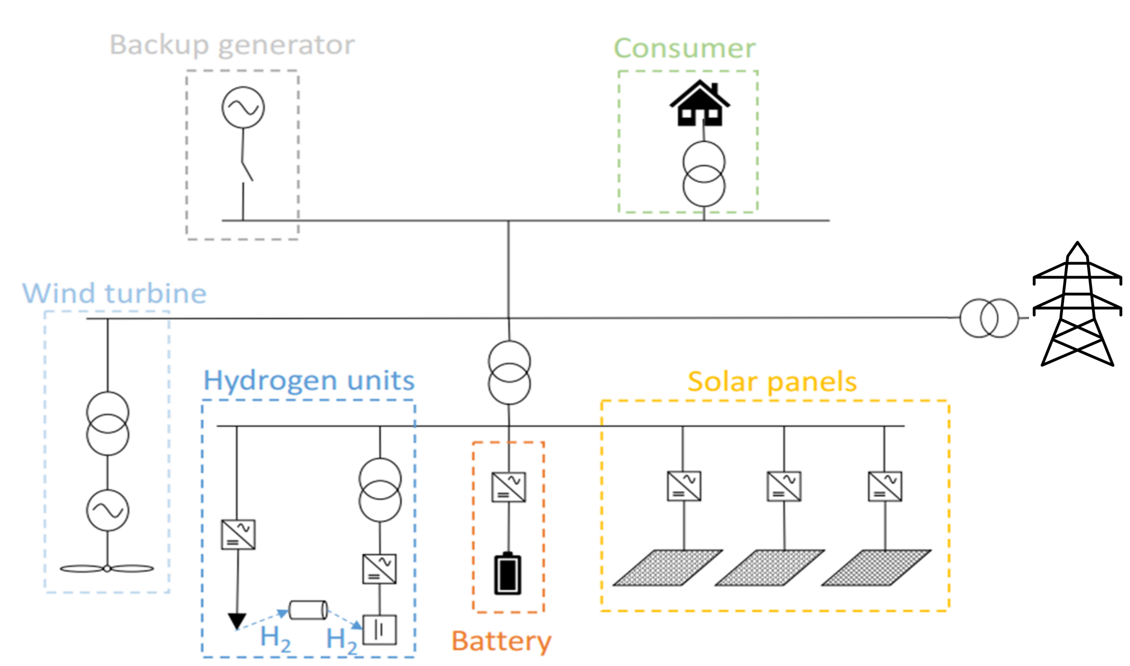

Figure 2: Adapted microgrid illustration from Nina Lindholm 2020[2]

- **Study Focus:** Study assesses how different variants of resilience integration shape the value of both ESS and transmission capacity:
  - **Scenario 1 (S1):** Robust case, requires full reliability, expecting worst-case for failure of main grid & deficit of renewable prod. of microgrid
  - **Scenario 2 (S2):** Robust case for grid failures, stochastic for renewable production of the microgrid based on probabilities & forecasts
  - **Scenario 3 (S3):** Stochastic estimation for both grid failures and renewable production deficits based on probabilities & forecasts
  - **Scenario 4 (S4):** Stochastic estimation including cascading failures and their correlation with renewable production

Implications

- **Local Solutions:** Highlights the potential to build a resilient power system using local production capabilities
- **Cost Implications of Resilience:** Assesses the cost implications of achieving resilience through local solutions instead of reliance on the main grid (and grid expansion)
- **Modeling and Assessment:** Demonstrates how different resilience requirements can be modeled and evaluated within the context of a microgrid with limited transmission capacity, addressing congestion and supply issues to maintain system reliability

References

1. P. Aaslid, M. Korpås, M. M. Belsnes and O. B. Fosso, "Stochastic Optimization of Microgrid Operation With Renewable Generation and Energy Storages," in IEEE Transactions on Sustainable Energy, vol. 13, no. 3, pp. 1481-1491, July 2022, doi: 10.1109/TSTE.2022.3156069.
2. Nina Lindholm, "Islanded Microgrids: a Predictive Approach to Control Operation", June 2020, under https://ntnuopen.ntnu.no/ntnu-xmlui/handle/11250/2778239

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