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RISK SEGMENTATION AND PORTFOLIO ANALYSIS FOR PARETO DOMINANCE IN HIGH RENEWABLE PENETRATION AND STORAGE RESERVES

PERFORMANCE-BASED ENERGY RESOURCE FEEDBACK, OPTIMIZATION, AND RISK MANAGEMENT (PERFORM)

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Task 6 - Stability of real time operations under steady state risk management

- Investigate new reserve products intended to provide primary frequency control
- Validate via time simulations the stability limits that are the outcome of the modified UC problem
- Study optimal procurement of the services intended to provide frequency control with respect to time and space
- Study potential incentives for inverter-based devices to provide these products such as pay-for-performance
- Incorporate operating reserve demand curves (ORDCs) into reserve requirements, while incorporating risk tranching

Primary Frequency Response Reserve types

Primary Frequency Response (PFR) Reserve

- Proportional to frequency deviation (e.g. droop control)
- Intended for traditional generators that exhibit ramping constraints

Fast Frequency Response (FFR) Reserve

- Step response to frequency (e.g. under frequency load shedding)
- Intended for load shed or inverter-based generation
    - Fast acting resources without ramping constraints

Virtual Inertia (VI) Reserve

- Derivative response to the frequency (e.g. synchronous inertia)
- Intended for inverter-based generation
    - Fast acting resources without ramping constraints

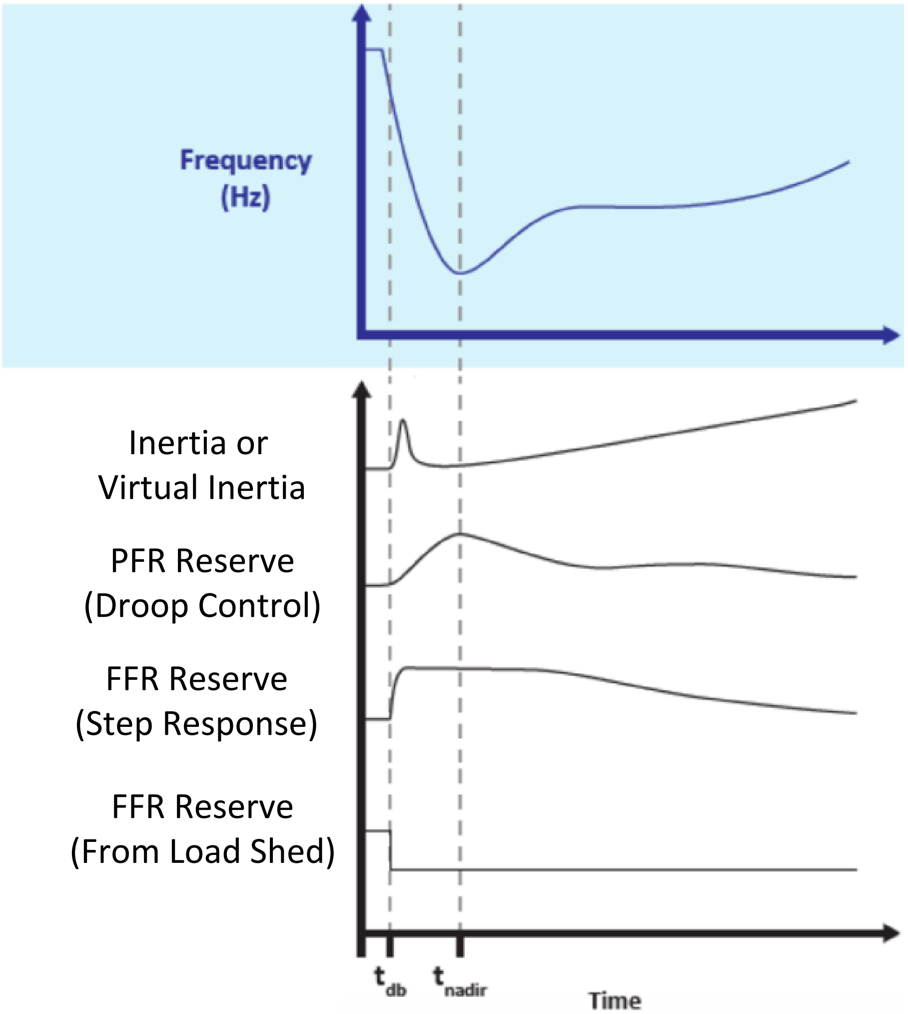

Figure: Different response types. Figure from [SNL1].

[SNL1] NERC. "Fast frequency response concepts and bulk power. System reliability needs. Technical Report, North American Electric Reliability Corporation

Reserve Requirement (PFR Reserve Limits)

Requirement Description

Requirement (1):
There must be sufficient reserve to cover an outage of size L

Requirement (2):
PFR reserve is limited based on the generators' ramping ability

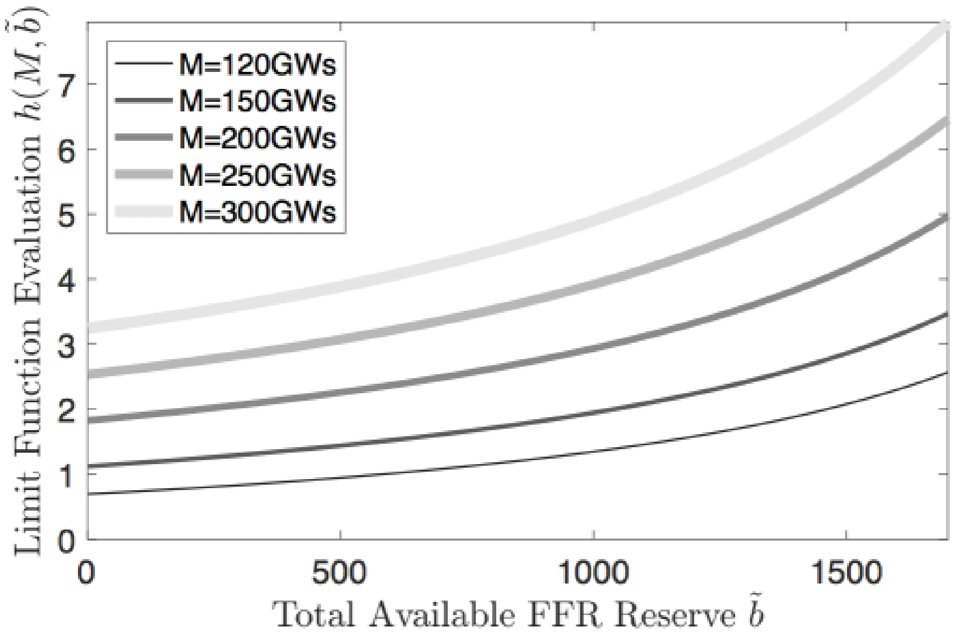

Figure: Function $h(M, 1^T b)$ with ERCOT parameters

Notation

- PFR reserve denoted r
  - PFR ramp rate denoted κ
- FFR reserve denoted b
- Inertia denoted M
- Accommodates outage of size L
- $h(M, 1^T b)$ is a function derived theoretically and verified empirically

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[SNL2] Garcia, Manuel, and Baldick, Ross. "Real-time co-optimization: Interdependent reserve types for primary frequency response." Proceedings of the Tenth ACM International Conference on Future Energy Systems. 2019.

Texas 2000 Bus Test Case

Test Case Details [SNL3, SNL4]

- Developed by Texas A&M. Open source and available for download in different formats. Steady state and dynamic data available
- 2000 bus representation of Texas (ERCOT)
  - Steady-state Matpower Data (Converted to EGRET)
  - Dynamic Power World Data (Converted to PSLF)
- 544 generators
  - Two largest generators ($L = 2750$ MW)
  - PFR generators: 50 largest natural gas
  - Assumed 163GWs of system inertia

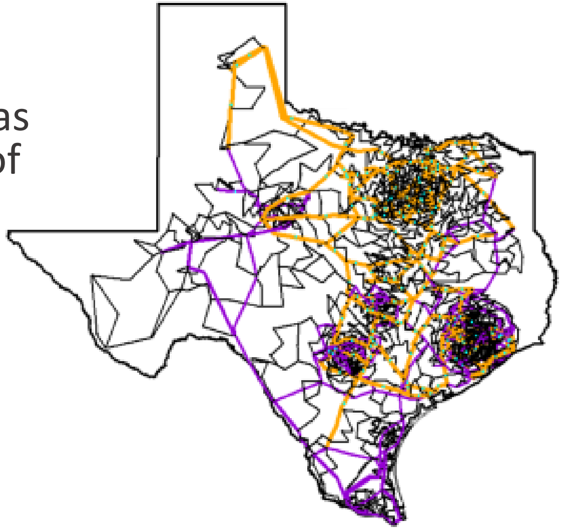
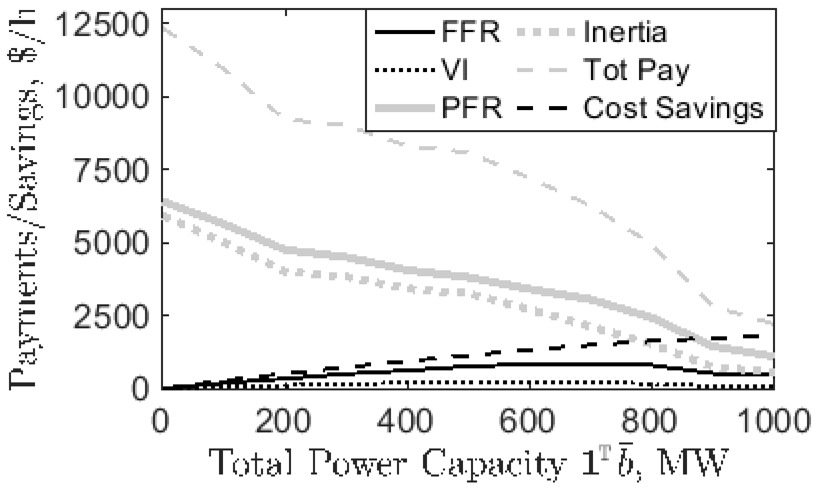


Figure: One-line diagram of Texas 2000 test case overlaid on top of Texas map

Figure: Reserve payments and cost savings versus total power capacity of inverter-based resources providing reserves.



High-Level Results

As more Inverter-based Resources (IBRs) provide primary frequency response reserve:

- total reserve payments decrease
- total costs decrease

Note: ISOs may not provide payments for synchronous inertia because it requires no reserve procurement.

[SNL3] Adam B Birch1eld, Ti Xu, Kathleen M Gegner, Komal S Shetye, and Thomas J Overbye. "Grid Structural Characteristics as Validation Criteria fo Synthetic Networks." IEEE Transactions on Power Systems 32.4 (2017), pp. 3258-3265

[SNL4] Ti Xu, Adam B Birchfield, and Thomas J Overbye. "Modeling, Tuning, and Validating System Dynamics in Synthetic Electric Grids." IEEE Transactions on Power Systems 33.6 (2018), pp. 6501-6509

Incentives for Inverter-Based Resources

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Pricing Incentives

- No incentive to provide PFR reserve
  - Lower Price than FFR reserve
  - Same energy requirement as FFR reserve
- Trade-off between VI and FFR Reserve
  - FFR reserve requires more energy reserve
    - Must be sustained for time Δt
    - Preferred by renewable generator
  - FFR reserve requires less energy reserve
    - Preferred by storage device

Results from Texas 2000 bus test case

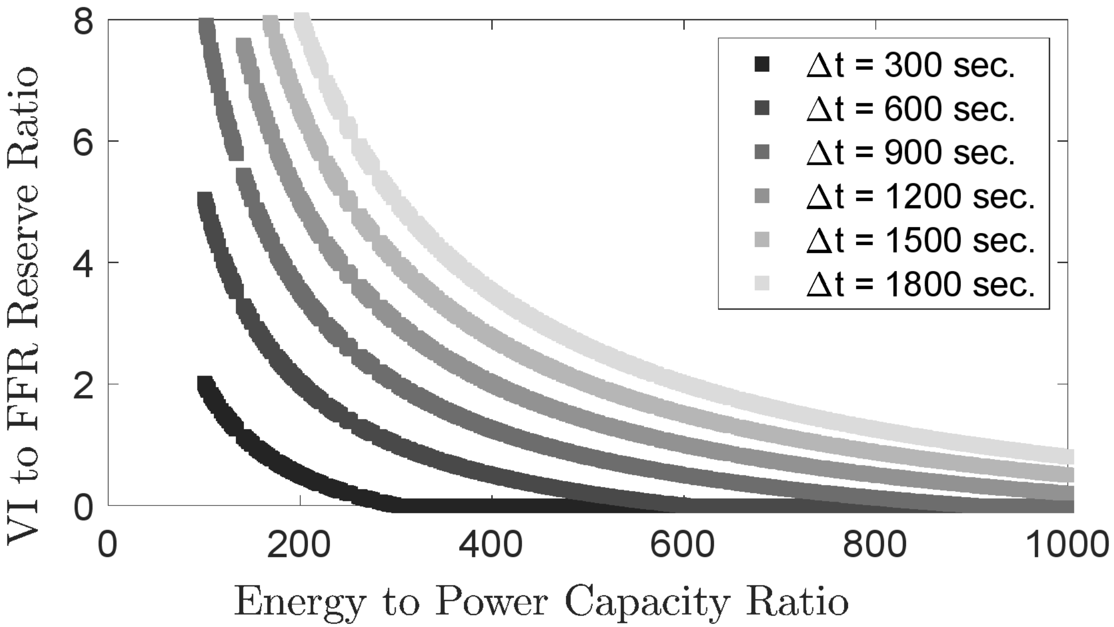

Figure: Profit maximizing VI to FFR reserve ratio given an IBR's energy to power capacity ratio. IBRs with low energy capacity prefer VI reserve.

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Acknowledgment

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