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Data Driven Modeling for Critical State Estimation in Power Grids

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Introduction

- Power system state estimation critical to ensure smooth grid operations
- **State estimation:** $z = Hx + e$
- **Data Injection Attacks:** spoof meter readings with $a = Hc$, so that error is undetected
- **LMP:** Locational Marginal Price
- **Problem Statement:** Given N buses, identify $k << N$ buses which can determine the system state (as represented by LMPs) accurately

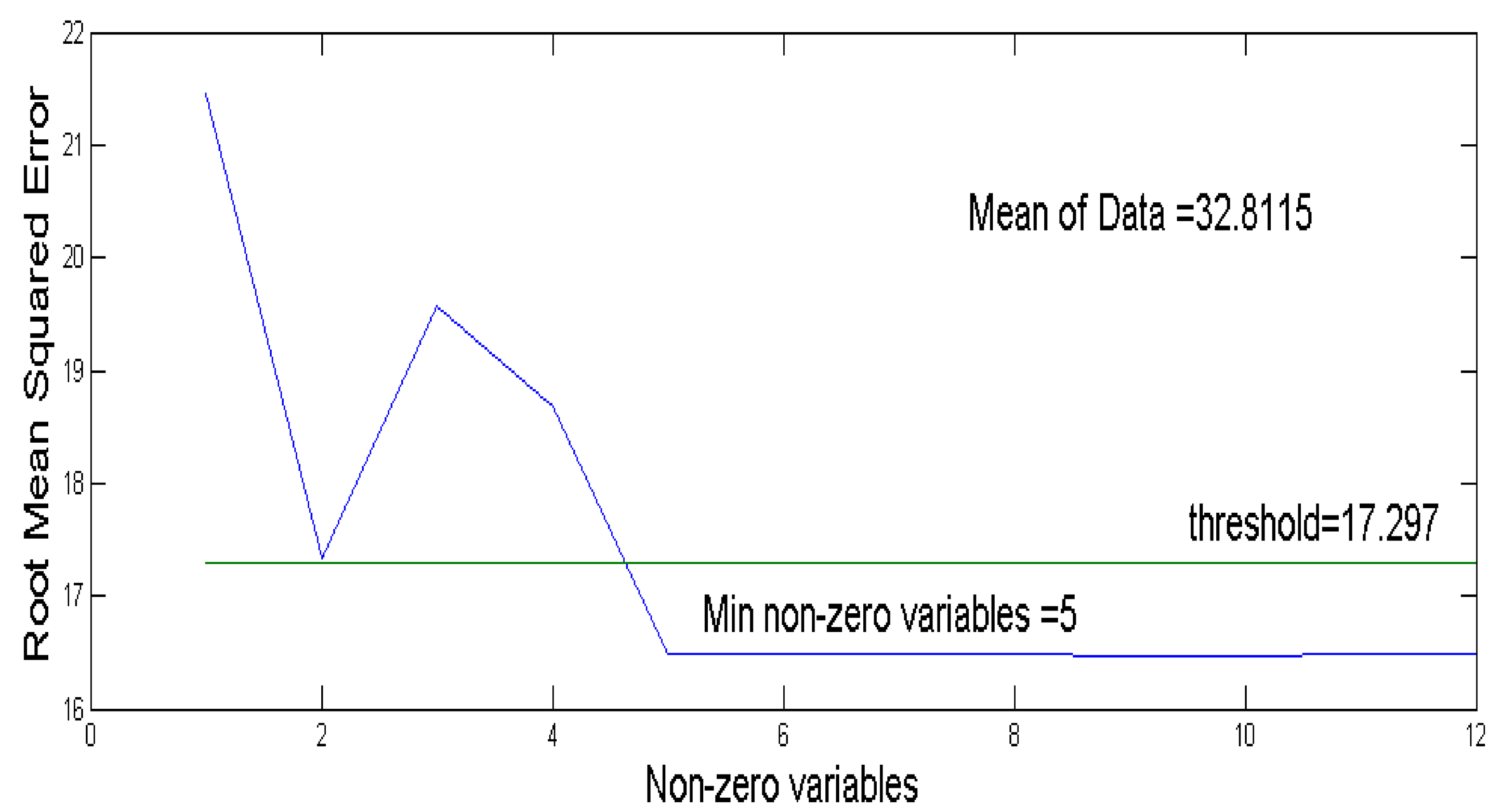
Exploiting Power Flow Structure

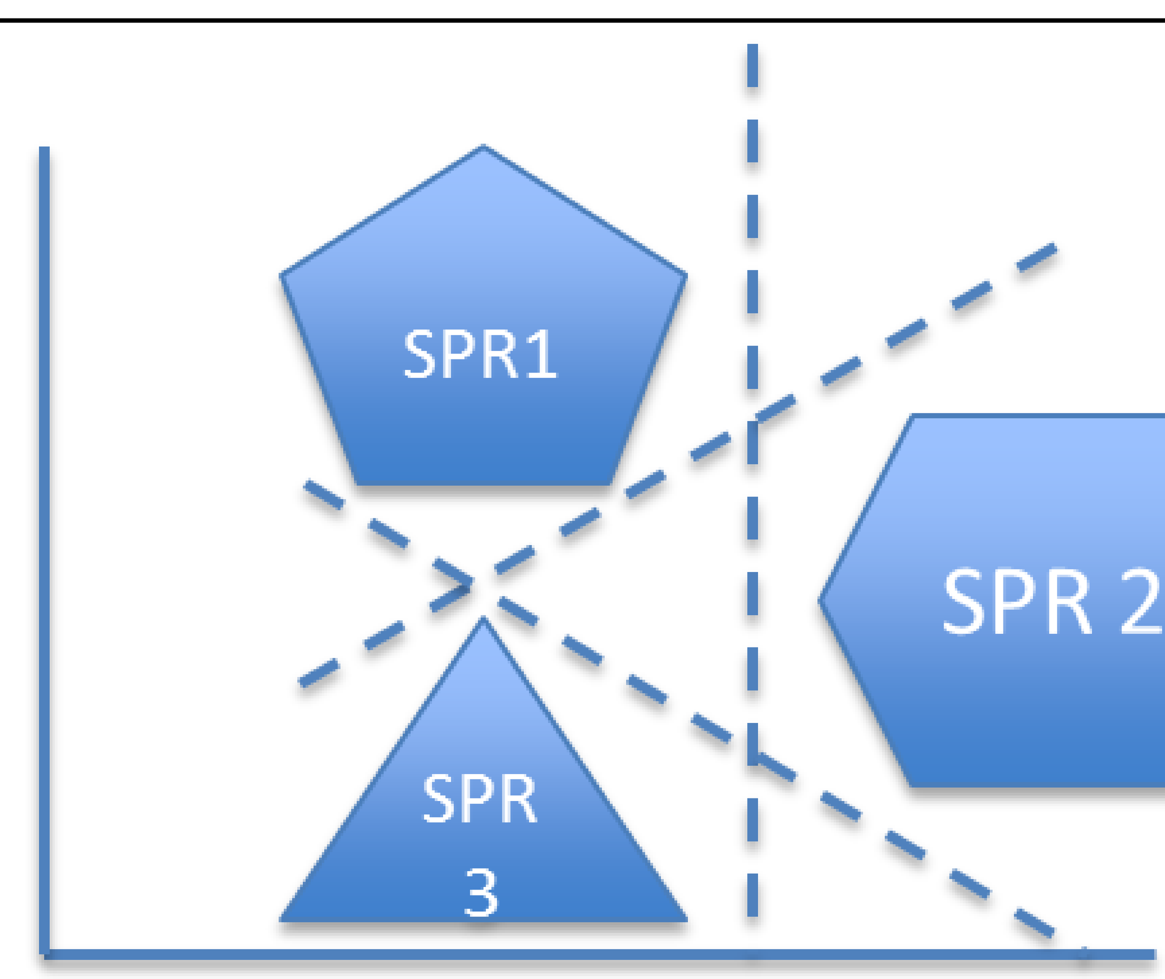
- **System Pattern Region:** Range of load-vectors for which same N equations become tight
- **Theorem:** Load pattern space can be partitioned into **disjoint convex sets** each of which correspond to a unique system pattern region
- Approach (linear cost function):
  - Preprocess historical data and identify l most frequent system patterns (using LMPs)
  - Generate $\frac{l(l-1)}{2}$ one-to-one SVM models
  - Use PCA on the R^{$\frac{l(l-1)}{2} \times n$} weight matrix to identify the minimum number of states which account for maximum variance (to meet threshold criteria)

Lasso Regression

$$\min\left(\frac{1}{2m}\sum_{i=1}^{m}\left(y_i-\beta_0-x_i^T\beta\right)^2+\lambda\sum_{j=1}^{n}\beta_j\right)$$

- **Inputs:** x: load vector, y: price
- **Outputs:** β weights for each bus
- Results:
  - Lasso with 10 fold validation
  - Just 4-5 buses ensure <5% deviation from 14 bus error rate
- Limitations: Low accuracy





Future Work

- Generalize for quadratic cost functions
- Challenge: LMP not unique for a region

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