DATA BASELINE TECHNIQUES TO DETERMINE PMU EVENTS

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PROJECT INFO AND DUKE PMU INSTALLATION

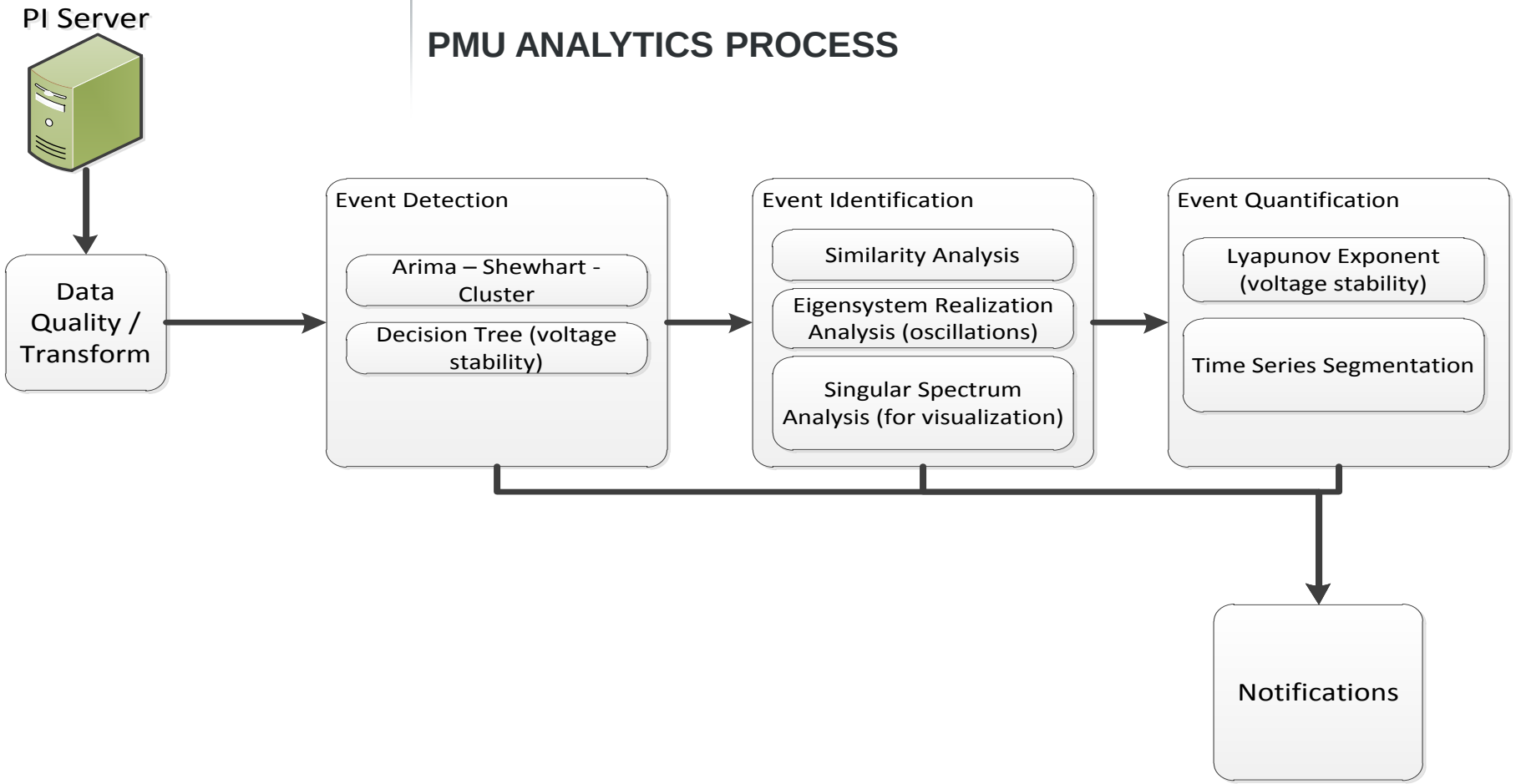
- Joint project with Duke Energy, NC State University Freedm center, and SAS
- PI Historian data from 100+ PMUs on Duke Carolinas transmission grid
- Develop analytics to:
  - Understand Steady State operation
  - Detect events on the network
  - Categorize the event on the network
  - Direct appropriate action based on the event
  - Capture data for post event analysis

HIGH SPEED VS. LARGE VOLUME

Streaming Data
- High speed, real-time
- Continuous analysis
- Specific historical context

Big Data
- Large volume
- On-demand analysis
- Full historical context

PMU ANALYTICS PROCESS



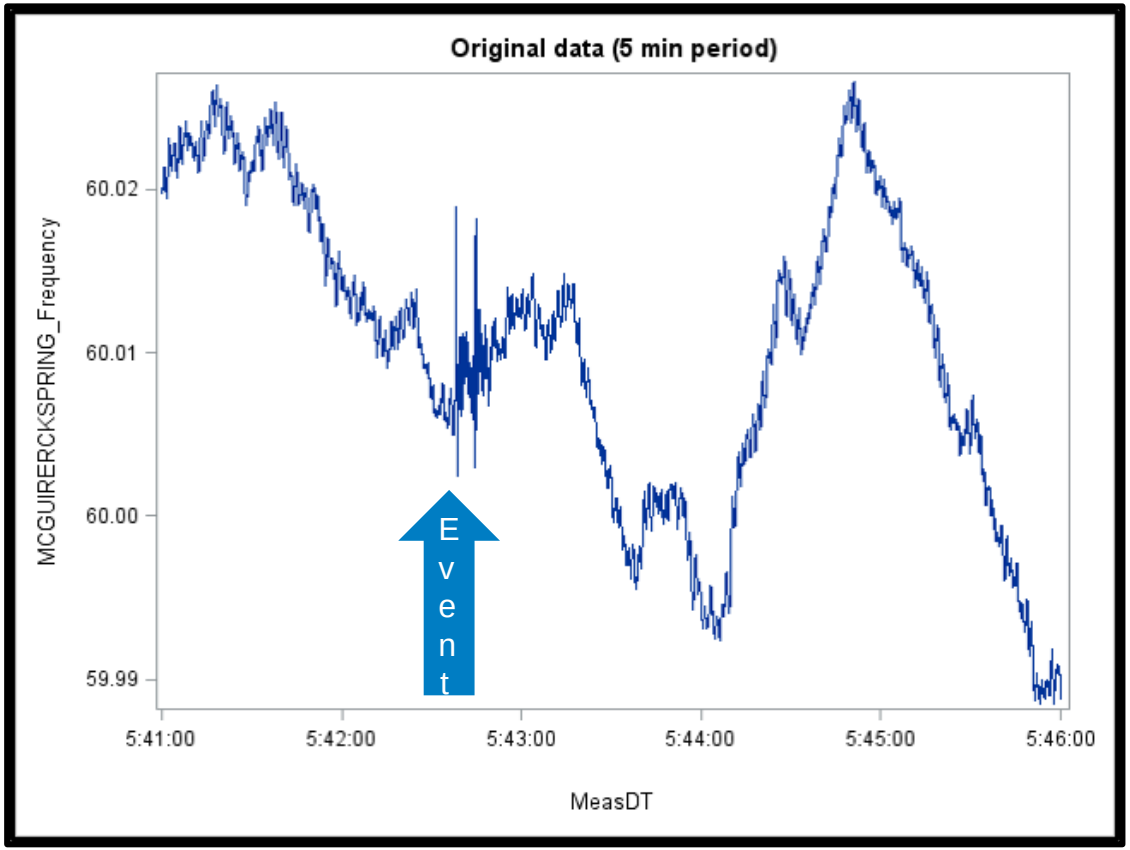
DATA PREPARATION AND QUALITY

- Working with PI System compressed data
- Use uncompressed tag (Frequency) to detect missing time periods
- Difference between missing data and bad data
- Monitor status tag. Status may be updated at multiple points in the data chain
  - At the PMU, at the data collector, in the PI System
  - Sometimes status in the measurement field
- Cross check values for consistency
  - Freq = 0, Angle = 45 (loss of GPS signal)
  - Some PMUs were configured differently (Freq tag), this was corrected
  - Missing measurement during phase angle “wrap” – do not interpolate
- Calculate phase angle differences between PMU pairs
- Automate data preparations and analytics

FREQUENCY DATA FROM LINE TRIP EVENT

Problem: how to detect events that occur within specs

- Frequency varies within engineering specifications
- Events occur, but are still within specification

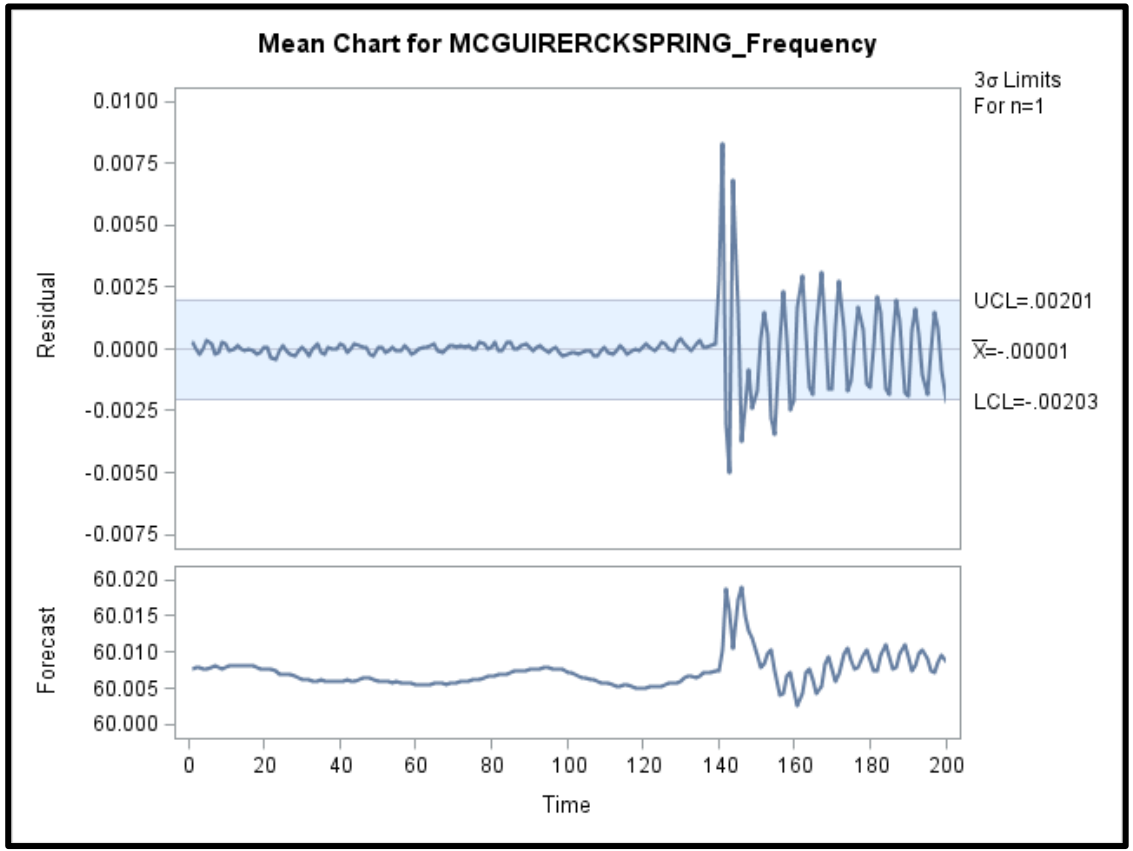


CONTROL CHART ANALYSIS OF RESIDUALS

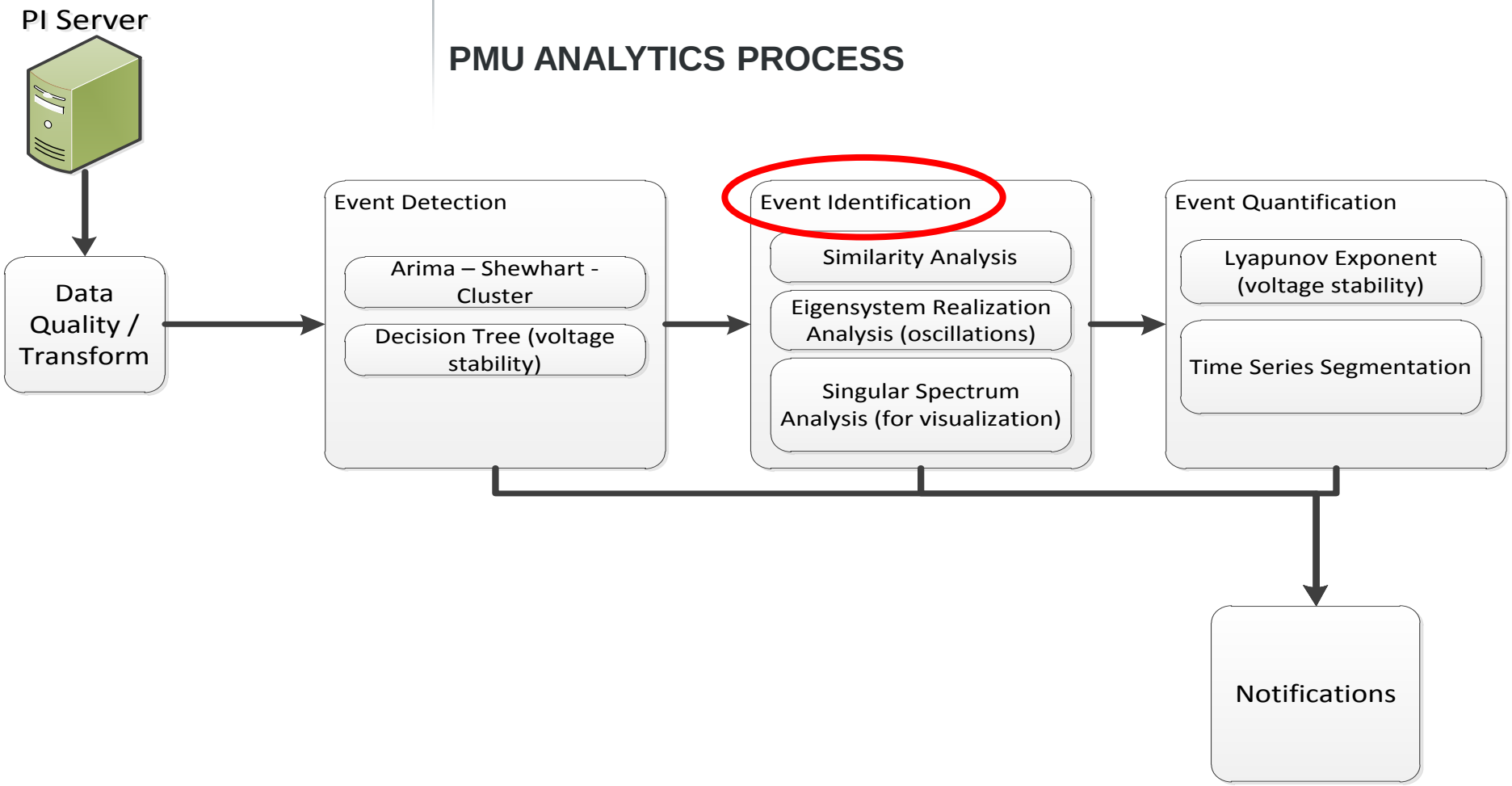
Solution: Forecast expected values and detect deviations

Residual – difference from expected value

Expected value based on times series model



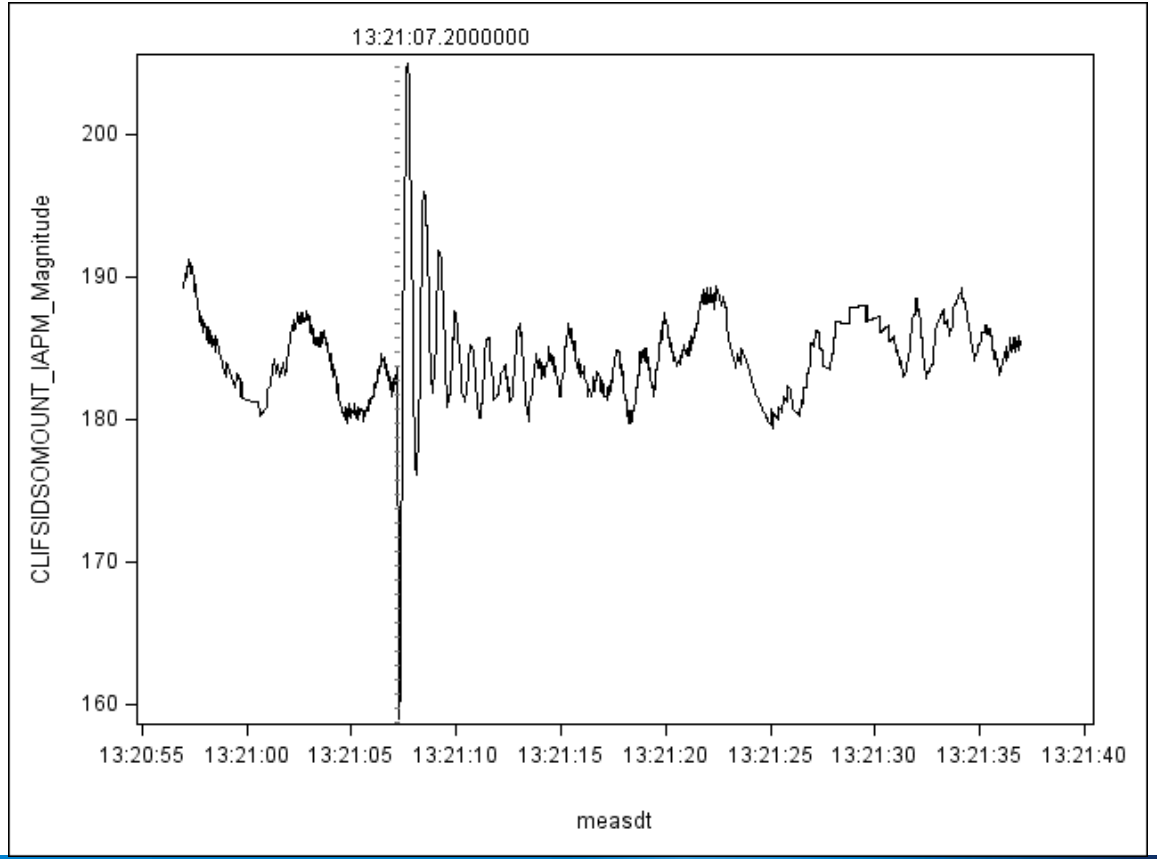
PMU ANALYTICS PROCESS



DETAIL CHART FOR EVENT

Problem: How to take incoming events and categorize them

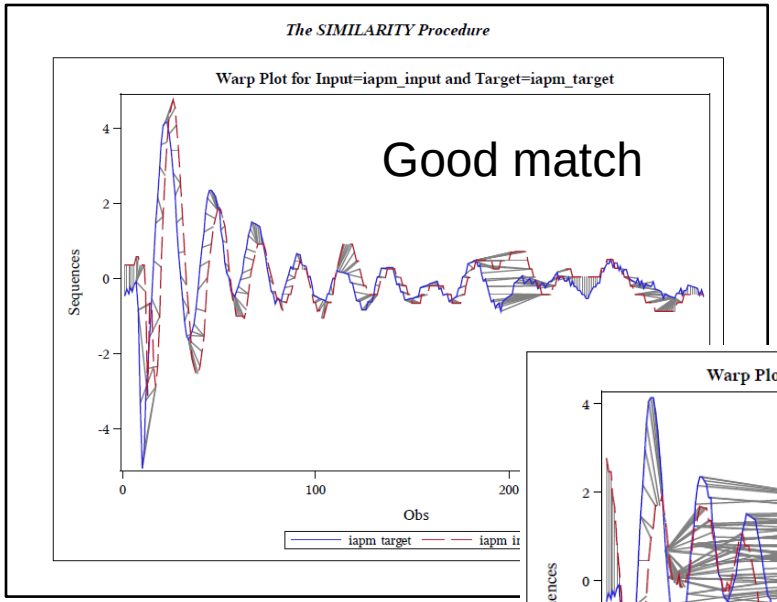
- Current oscillates after event, but then dampens down to normal

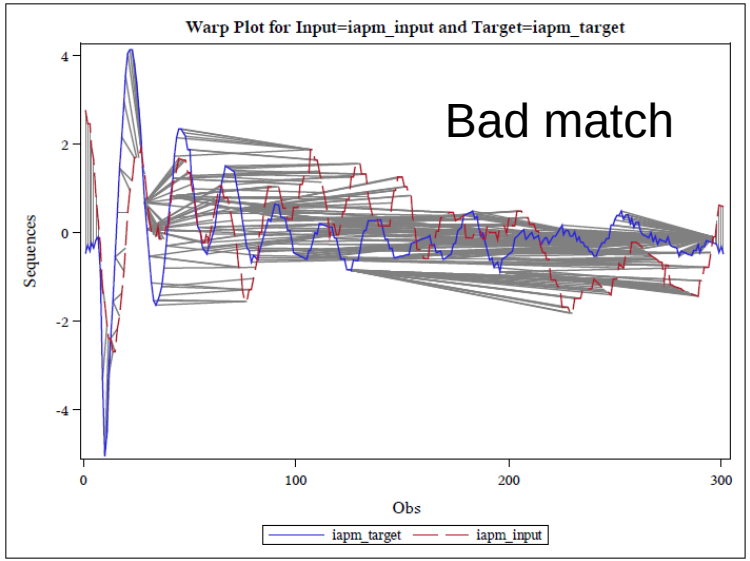


SIMILARITY ANALYSIS

Solution: Use similarity analysis and time-series data mining to categorize data streams

- Similarity between incoming stream and reference time series are measured and quantified

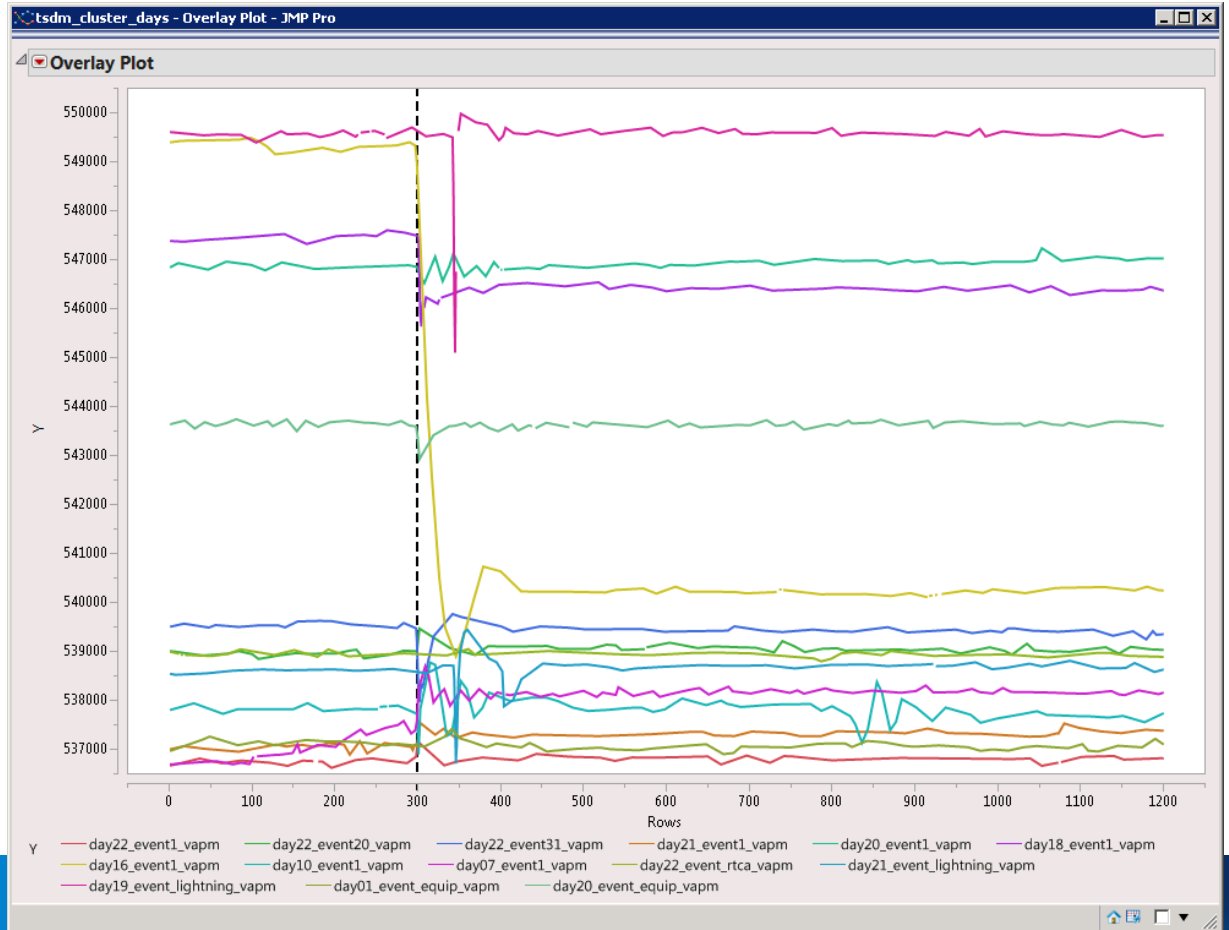




MULTIPLE EVENTS ALIGNED BY EVENT TIME

Problem: How to build a reference library of various event types

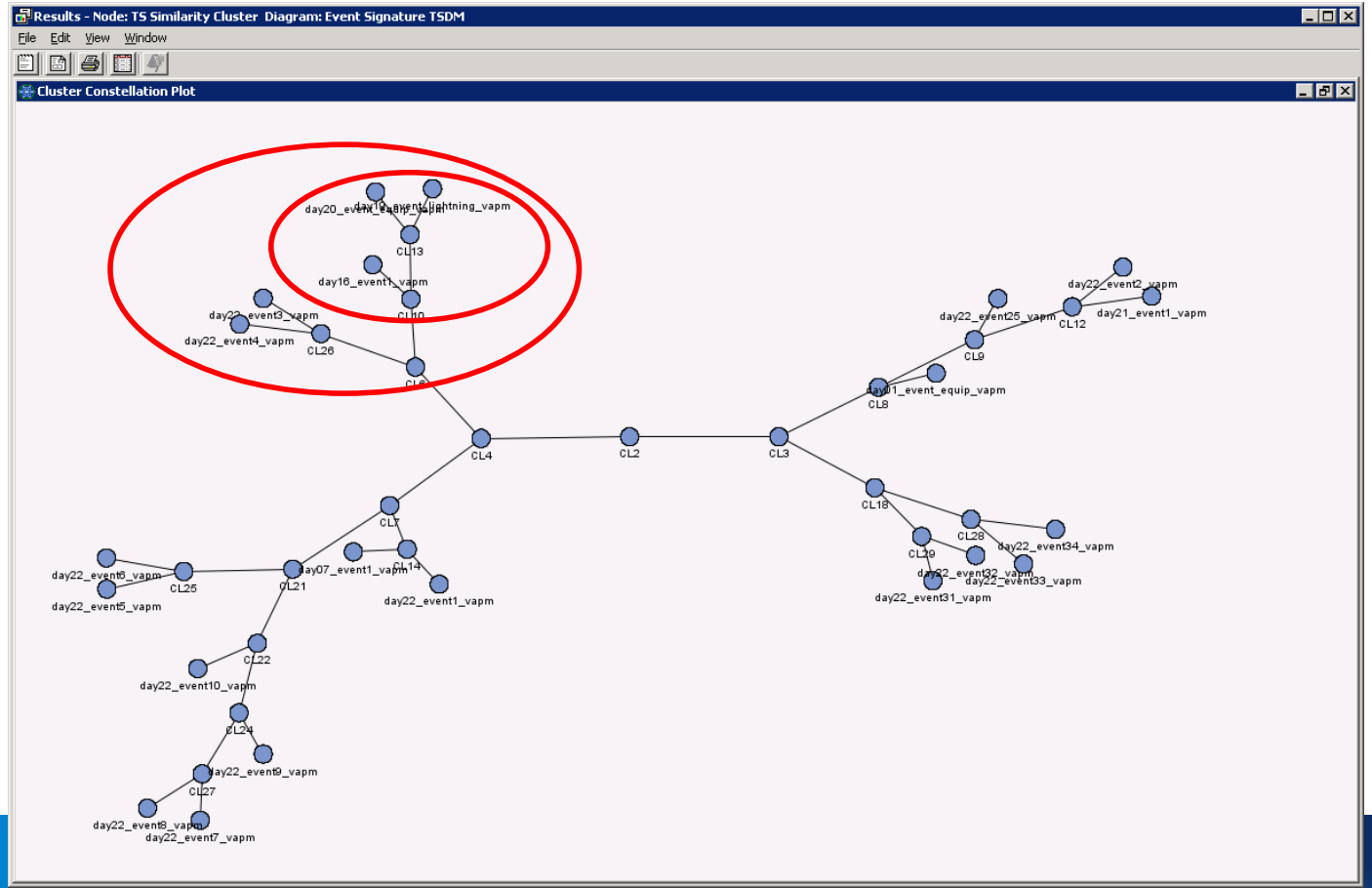
- Historical data aligned by time of event



TIME-SERIES DATA MINING, CLUSTER ANALYSIS

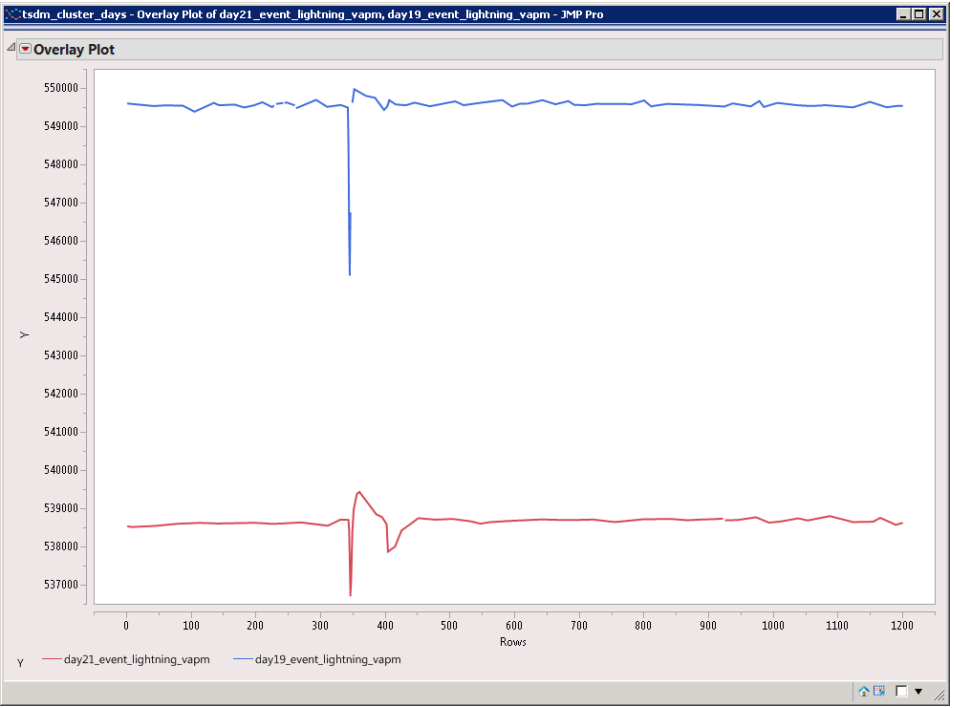
Solution: Use time-series clustering to group similar data patterns

- Documented events provide cluster identification



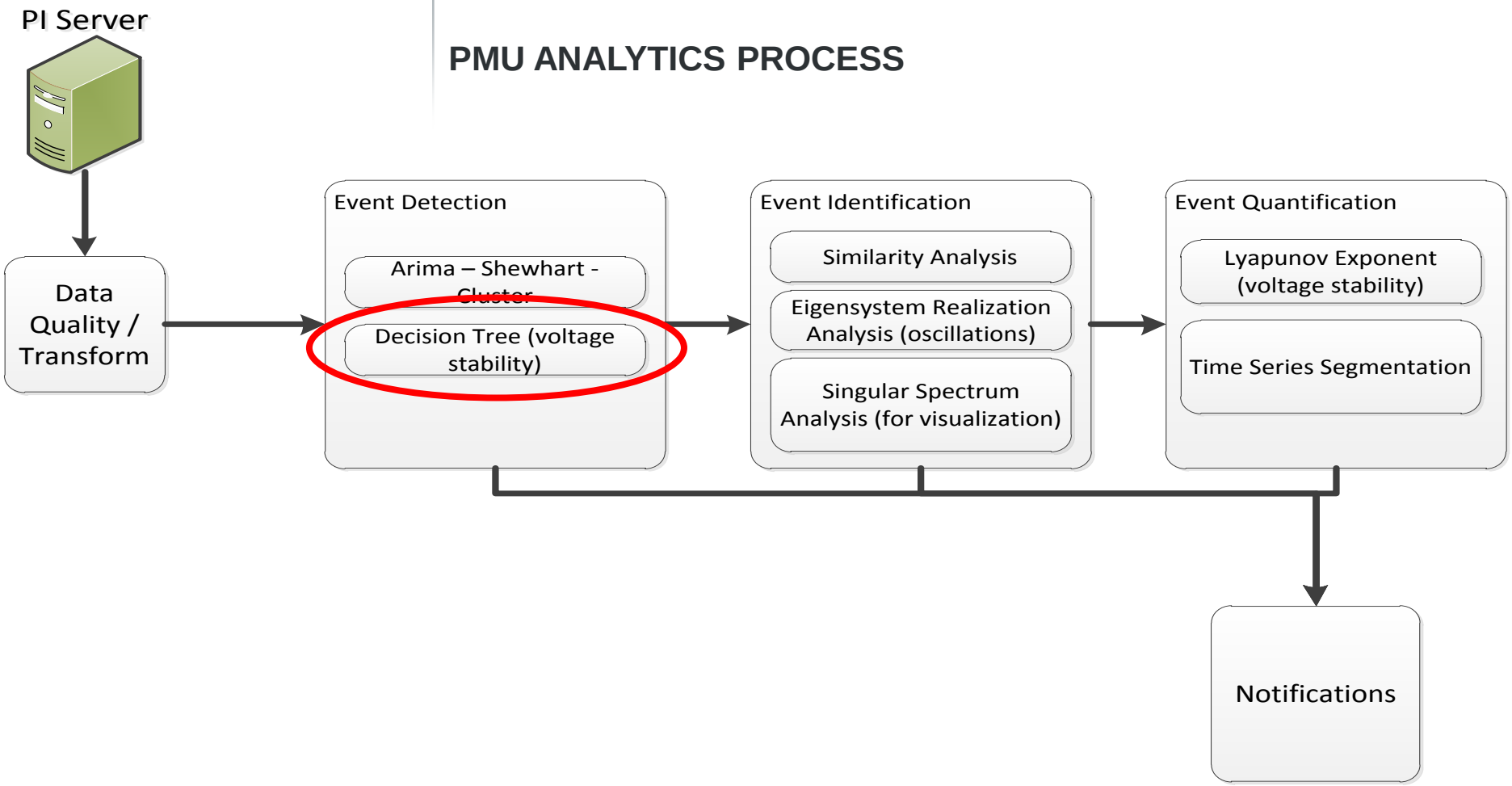
EXAMPLE CLUSTERS

Lightning event



Equipment issue

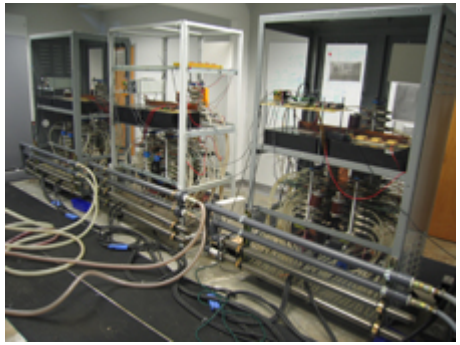
PMU ANALYTICS PROCESS



USING SIMULATION DATA FOR PREDICTION

Problem: how to predict events which are very rare

- Need to detect situations that are vulnerable for voltage collapse



Reference: IEEE Transactions on Power Systems, Vol 24, No 2, Diao, et al.

DETERMINING CRITICAL SYSTEM STATES

Solution: Learning loop system using simulation data and predictive models

1. Use PSSE to generate cases for voltage stability
2. Build decision tree to identify vulnerable situations
3. Use rules to review historical data and determine exposure
4. Use rules to monitor real time data to alert on vulnerable situations

Gives warning before event, while still actionable

CONCLUSION

- Analytic perspective on synchrophasor data
- Big data and streaming data techniques
- Various analytic techniques used
- Match technique to scenario

Acknowledgments:

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