Distribution State Estimation:
Implementation Challenges and Toolkit
Power System State Estimation

- A mathematical method with which underlying power network behavior can be determined from operating information.

Set of Measurements

+ Network Model

+ Known Network Information

Most Likely Network State (Voltages, Flows, …)
Provided Data versus DSE Benefits

- Accurate Network Model
- Granular Forecasts
- Measurement Prevalence

Requires Redundancy in Measurements

- Distribution State Estimator

- Accurate Voltages at All Buses
- Accurate Flows on All Lines
- Detection of Bad Measurements
- Network Model Correction

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DSE Toolkit

• SGS has prepared a software toolkit for New York utilities and other interested parties:
  • Set up DSE on an example network
  • Explore DSE concepts in a sandbox environment
    • Measurement placement
    • Observability
    • Accuracy of resulting state

• Run test cases:
  1. Determining necessary measurements for an observable network
  2. Identifying and removing bad data with limited measurements
  3. Improving performance with redundant measurements
Example DSE Implementation

• Simple radial network
• Measurements at substation, end of line
• 15-minute P&Q forecasts at each bus (AMI-powered)
• We can use the DSE toolkit to determine:
  • This system is observable.
  • State estimation improves upon load flow and load allocation methods
  • This system cannot detect bad data.
  • How performance can improve with more measurements
Best Practices for Distribution State Estimation

1. Set expectations based on measurement capability
   • Full benefits of DSE require extensive measurement placement.

2. Develop CIM-based on-line network model
   • Update control actions, automation, and manual switches in real time.

3. Use granular forecasts and load allocation
   • Forecasts will usually make up vast majority of measurements.
   • Machine learning with AMI and weather data improves DSE.
   • Feedback loop: DSE can improve forecasts, iterative process.

4. Leverage redundant measurements in the substation
   • Remove erroneous measurement devices
   • Detect incorrect switch positions.
DSE Minimum Requirements

- AMI
- Distribution Automation
- CIM
- 2 Data Points Per Node
- Up-to-Date Network Model
- Communication Infrastructure
- State Estimation Engine
- ADMS
- Distribution State Estimation
Questions and Discussion

Project materials will be available on the NYSERDA webpage:

Appendix Material
Benefits of DSE

1. Real-time visibility
   • Invaluable to many advanced distribution applications

2. Reducing uncertainty
   • Accuracy improvement based on most likely power flow
   • Feeds better data into most other advanced distribution applications

3. Bad data detection
   • Network model calibration

DSE is a powerful tool, but the benefits are entirely dependent on the data that can be provided by the utility.
Implementation Challenges

1. Not enough measurements
   • Almost no distribution system is observable without the use of load forecasts

2. Communication infrastructure
   • Network model & topology (switch status) must be updated in real time
   • Measurements relayed to control center with minimal delay
     • Considerations for AMI data collection

3. Uncertainty in available information
   • Un-modelled customer connections might preclude use of AMI
   • Over-reliance on load forecasts introduces error
Performance Improves with Redundancy

- Redundancy allows a better estimate of the power system state
  - Enables applications such as bad data detection and model calibration
- Forecasts should not be used to generate redundancy

Number of Measurement Points ($M$) vs. Size of Network ($N$)

- $M = N$
- $M \leq 2N$
- $M > 2N$