Distribution System State Estimation for Validating Network Models

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Motivation

Utility Awareness is Limited by Incomplete Measurements

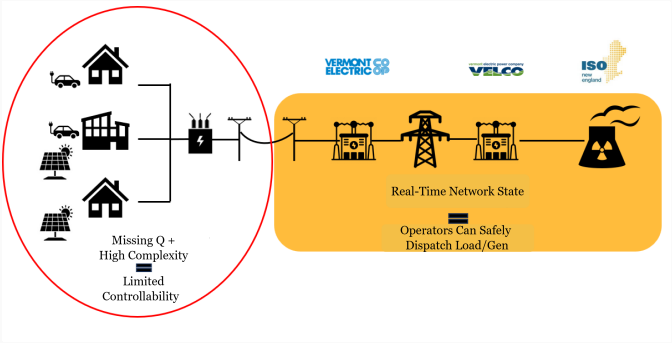

Figure 1: Distribution System Operator (DSO) Challenges[a]

[a] Cyril Brunner https://www.linkedin.com/pulse/grid-visibility-enabling-trust-among-distribution-planners-brunner-zwoye/

Need for State Estimation:

DSOs require real-time network state for operational decision-making.

Major Limitation

Missing reactive power measurements seriously limit accuracy of state estimation in determining network state.

Focus on Missing Reactive Power

What's used in Practice

Constant PF assumption is commonly used in powerflow and state estimation when Q is not directly measured, but this is really bad when the actual PF varies in time.

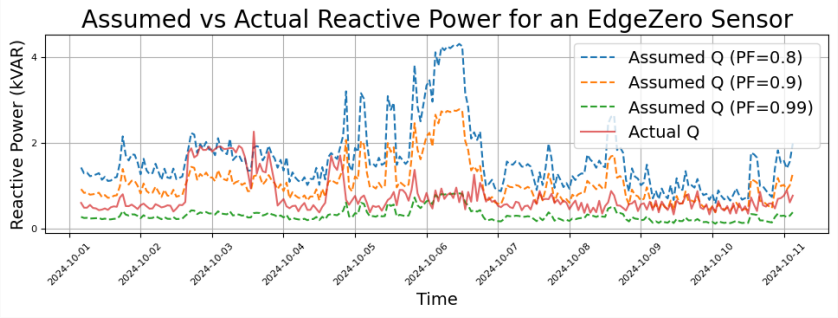

Figure 2: Constant PF Assumption Results in Large Estimation Errors

Impact of Missing Q On State Estimation

Voltage Estimates Suck

State Estimation using naive constant power factor assumption results in **massive** errors!

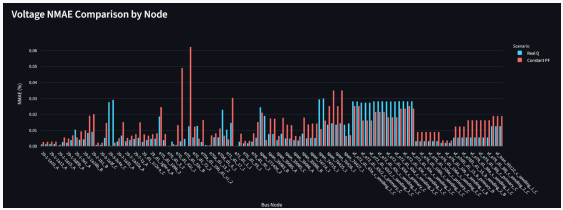

Figure 3: Voltage NMAE Comparison

Testcase	True Noisy Q	Constant PF (0.95)
GC-12-47-1	0.012%	0.066%
South Hero Feeder	0.029%	

Table 2. Voltage Estimates NMAE

Can We Do Better?

How to Achieve Real Time Awareness?

Use State Estimation:

1. Collect and synthesize measurements and network data
2. Obtain solution to state estimation problem

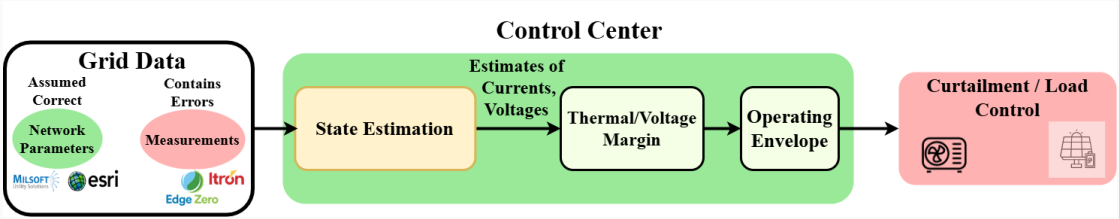

Figure 5: Role of State Estimation in DSO Operations

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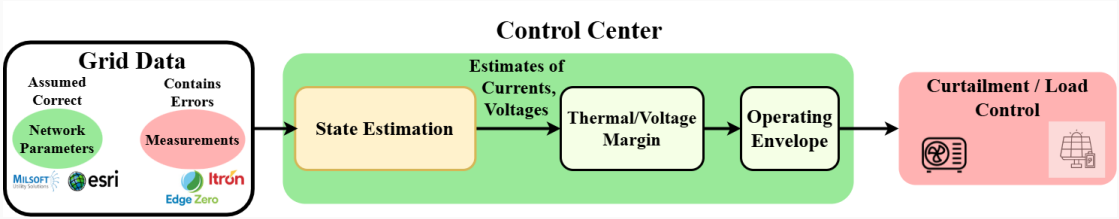

Figure 5: Role of State Estimation in DSO Operations

Limited Practical Studies in Research

Few distribution system state estimation studies investigate performance on real-world networks/measurements. Some limitations of related work:

- **Unrealistic Measurement Assumptions** ex) Widespread PMUs [1]
- **Small "Easy" Networks** [2]
- **Balanced Network Model** - not true in practice!

Key assumptions in this work:

- All Injections Measured
- Correct Network Model (at first)

[1] Lorenzo Zanni et al. "PMU-based linear state estimation of Lausanne subtransmission network: Experimental validation". In: *Electric Power Systems Research* 189 (2020), p. 106649

[2] Marta Vanin, Reinhilde D'hulst, and Dirk Van Hertem. "Distribution system state estimation for system identification and network model validation: An experience on a real low voltage network". In: *Sustainable Energy, Grids and Networks* (2025), p. 101710