Data-Driven Distributed (3D) Solar Visibility Prize

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Introduction

Background:

Power system *State Estimation* (SE) uses meter readings and other data to estimate the state of an electric power system.

Transmission System SE (TSSE):

- Uses data in the transmission network.
- Measures power flows, bus power injections, and voltages.
- Updates every 2 minutes for secure operations.

Distribution System State Estimation (DSSE):

- Handles complex distribution networks with unbalanced loads and fewer measurements.
- Adapts traditional TSSE methods.
- Enhanced by *Phasor Measurement Units* (PMUs) and *Advanced Metering Infrastructure* (AMI).
- Faces challenges from *Distributed Energy Resources* (DERs) and prosumers.

Importance of DSSE:

- Essential for real-time network management.
- Improves reliability, efficiency, and integration of renewable energy sources.

Future developments in DSSE will support modern power systems.

Problem Statement:

Development of various DSSE methodologies over two decades.

Remaining challenges:

- Limited data access
- Need for better communication and data processing

DER integration, e.g., solar panels, *Electric Vehicles* (EVs) increases complexity.

New methods needed to:

- Handle large, diverse data sets
- Improve feeder modeling
- Enhance *Transmission System Operators* (TSO) and *Distribution System Operators* (DSO) coordination

Advanced technologies:

- Edge computing
- Big data analytics
- Quantum computing

Closer TSO-DSO cooperation is crucial.

Goals: manage evolving power system demands, ensure efficient and reliable operations.

Objectives

Calculate 15-minute State Estimation Skill by:

- Adding *Mean Absolute Error* (MAE) of state variables
- Normalized count of accurately detected and identified bad data
- Normalized count of accurately detected and identified topology changes

Each set contains either bad data or topology changes, not both.

Issues are not flagged beforehand.

Aim to detect and identify issues correctly:

- Penalties for false reports
- Bonuses for accurate identifications

For bad data:

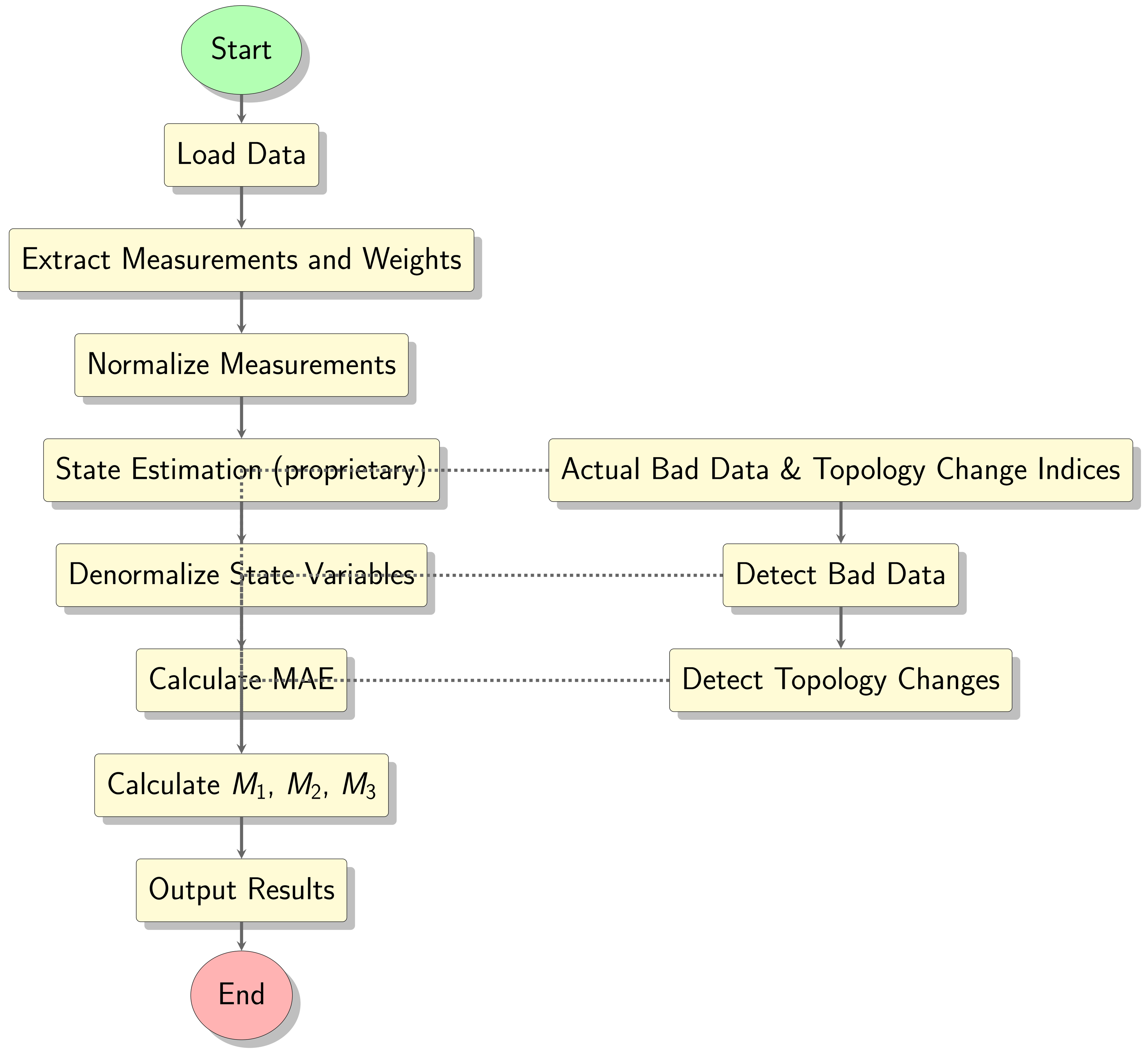
- Provide measurement identity and location
- Use scalable detection methods

For topology changes:

- Provide switch number and location
- Use scalable detection algorithms

Manual or arbitrary detection methods are not acceptable.

Methodology & Approach



Pseudocode

Data: Measurement data from CSV file
Result: Overall Skill Score
Start;
Load Data;
while *data available* **do**
  Load measurement data from CSV file;
end

Preprocess Data;
while *data not processed* **do**
  Extract relevant measurements and weights;
  Normalize the measurements;
end

State Estimation;
while *state not estimated* **do**
  Apply the proprietary SE method;
  Optimize the state variables;
end

Calculate MAE;
while *error not calculated* **do**
  Compute the MAE between estimated and actual values;
end

Calculate Metrics;
while *metrics not calculated* **do**
  M_1 **for Voltage Magnitudes:** Accuracy of voltage magnitude estimates;
  M_1 **for Voltage Angles:** Accuracy of voltage angle estimates;
  M_2 **for Bad Data Detection:** Identify and evaluate detection of bad data points;
  M_3 **for Topology Changes:** Identify and evaluate detection of changes in network topology;
end

Output Results;
while *results not output* **do**
  Print the results, including the overall skill score;
end
End;

Preliminary Results

$X_{MAE} = 9.726446058784236\text{e-}17$; M_1 for Voltage Magnitudes $= 1.0$
M_1 for Voltage Angles $= 1.0$; $M_2 = 0.2$; $M_3 = 0.2$
Overall Skill: 2.4000000000000004