Study Committee C2

Power System Operation and Control

Paper ID-10548

# State Estimation in Medium Voltage Distribution Networks using Pseudo-Measurements

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## Motivation

- Changing grid topology.
- Rise in Distributed Energy Resources (DERs) penetration.
- Important to continuously monitor the grid state.
- Distribution System State Estimator (DSSE) is of prominent interest.

**The challenge**

- Grid modelling has lot of assumptions.
- Better load modelling techniques needed for better idea.
- Planning for future scenarios.

## Distribution System State Estimation (DSSE)

**Problem Formulation**

- Power system state need to be always known.
- Voltage and Current based approaches are common to formulate the states.
- Voltage based approach is taken here owing to faster convergence.
- Various inputs can be considered.

**Solution method employed**

- Conventional Weighted Least Squares method is employed here.
- Variance of the input are the weights.
- Three type of inputs- Real, Virtual and Pseudo.

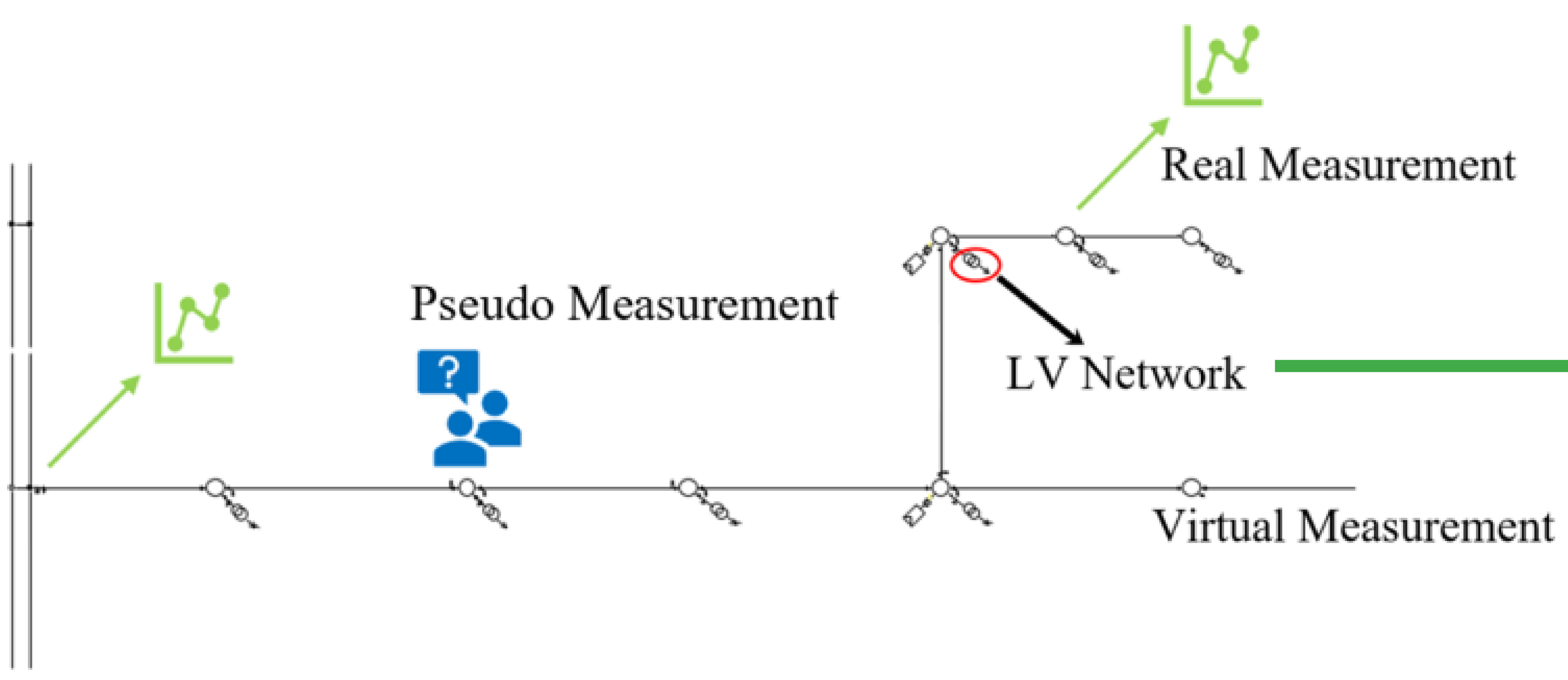


Figure 1. Grid Scenario

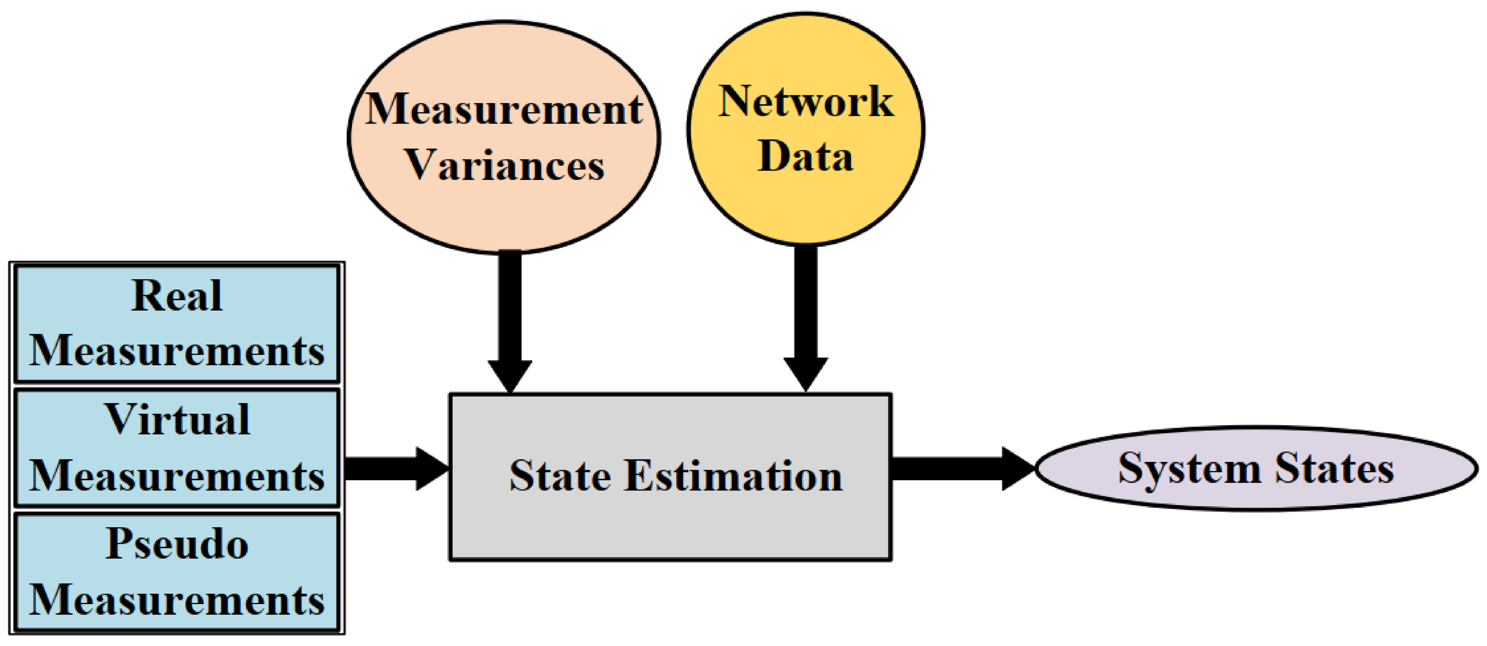


Figure 2. DSSE Functional Block

## The Approach

- Currently, LV network is not modelled accurately and considered as a black box.
- Stochastic LV network power flow is proposed here.
- Detailed cable models are considered.
- Gaussian Mixture (GM) load model is used to represent individual household (probability density functions of powers).
- Each appliance (PV,EV, heat pump) is modelled with their own time-varying PDF's (in Gaia software).
- Latin Hypercube based Monte Carlo random sampling used to perform power flow calculations.
- Normal approximation is used for aggregate load.

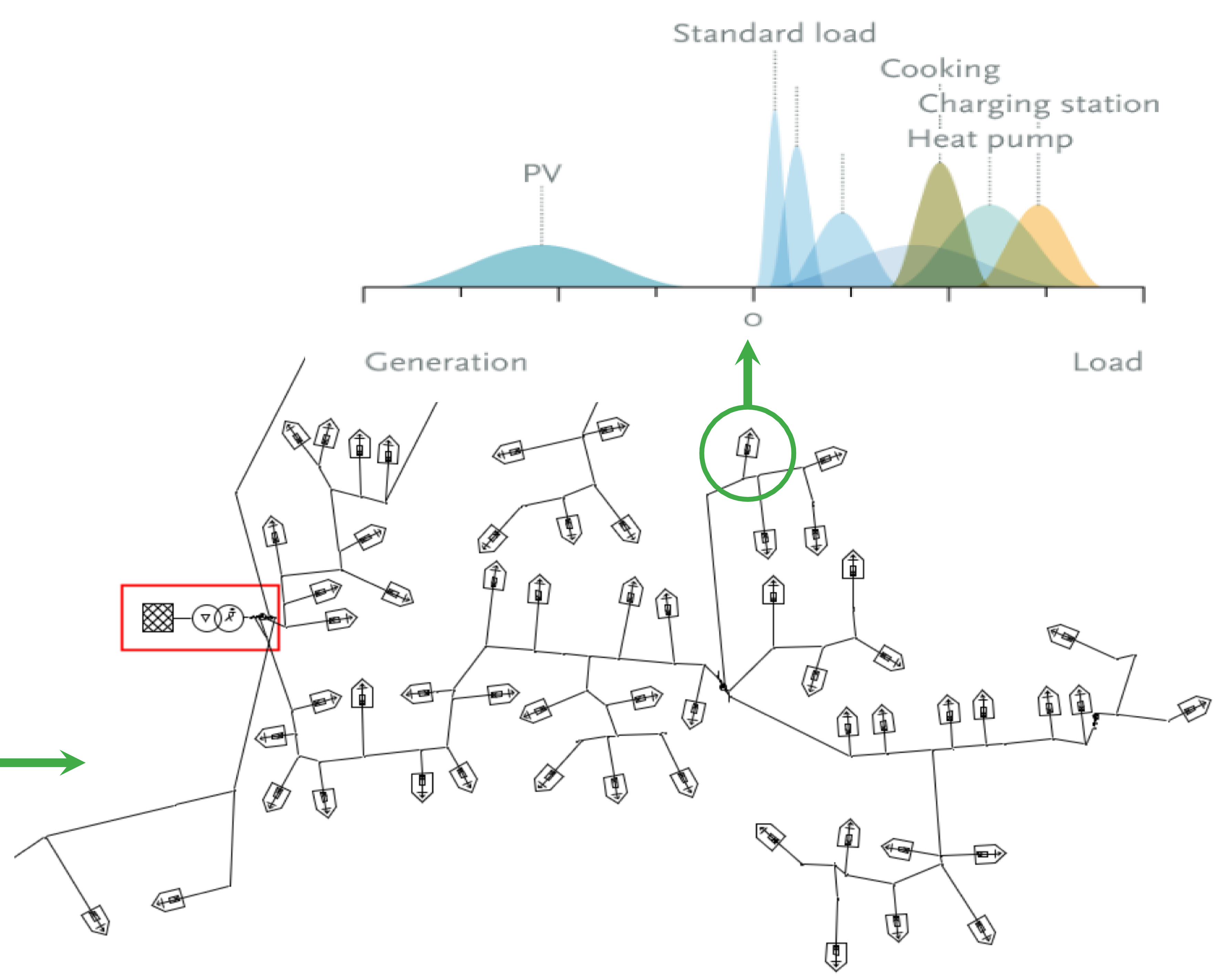


Figure 3. A sample LV network and Household level PDF's

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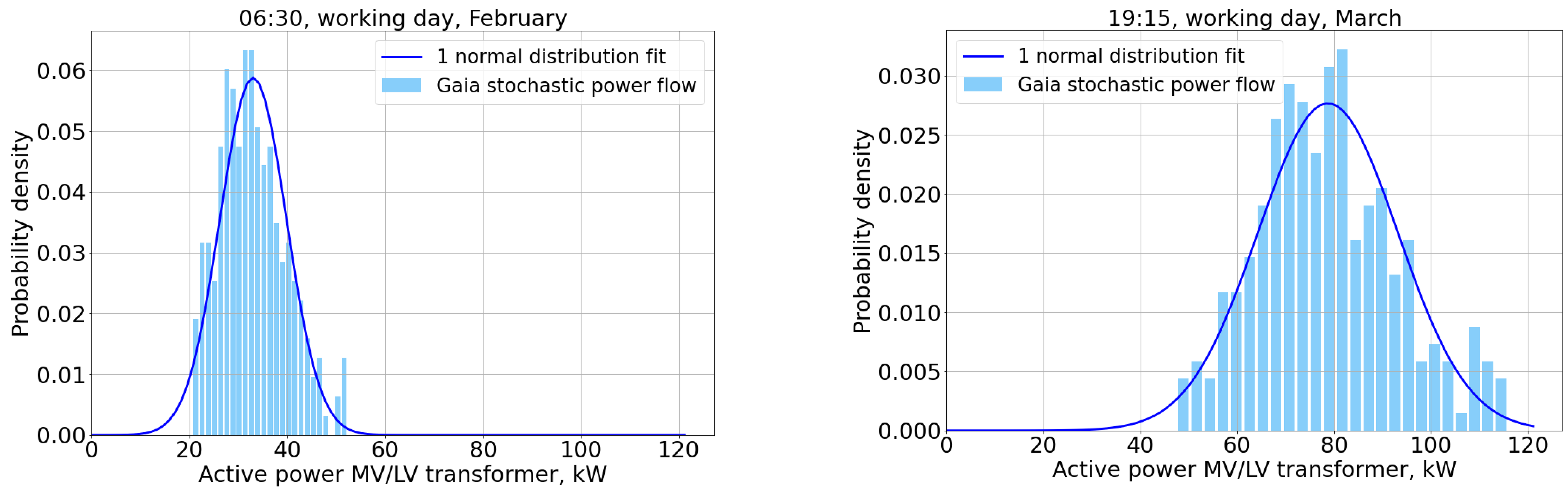


Figure 4. Normal distribution fitting of aggregated households

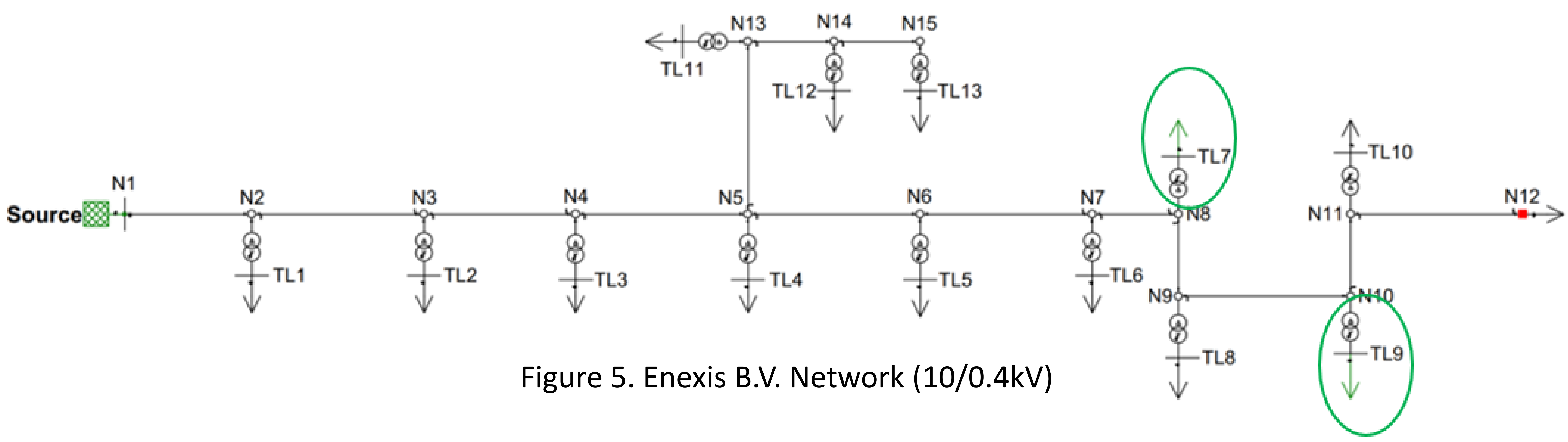


Figure 5. Enexis B.V. Network (10/0.4kV)

## Objects of investigation

Two typical Dutch Distribution Networks are considered and tested with this algorithm.

**Enexis BV network description**

- 28 nodes : 13 connected to LV network equivalent loads and one to a MV level consumer (N12).
- General overview of the loading profile generated.
- This implies, historical data previously available is considered to generate a approximated loading profile behavior.
- Network and stochastic household behavior modelled using Gaia (Phase2Phase).

**Stedin BV network description**

- 28 nodes : 15 connected to household loads and one to a MV level consumer (see paper for more).
- General overview of the loading profile over the entire year generated by the company experts.

Assumption: Grid topology is constant as well as free from faults and failure in components.

## Studies

**Enexis Network**

- Only measurement at node TL5 is considered.
- Proposed LV stochastic load flow model is used for other nodes.
- The nodes in green have measurement data and are used for validation purpose.
- The validation is done for the peak load moment in April 2021 at 18:00 as shown in Figure 6.

**Stedin Network**

- Two scenarios are considered for thirty days period with measurements being 5 min apart.
- Scenario 1 takes power injections as input and scenario 2 also considers voltage measurements at the nodes.

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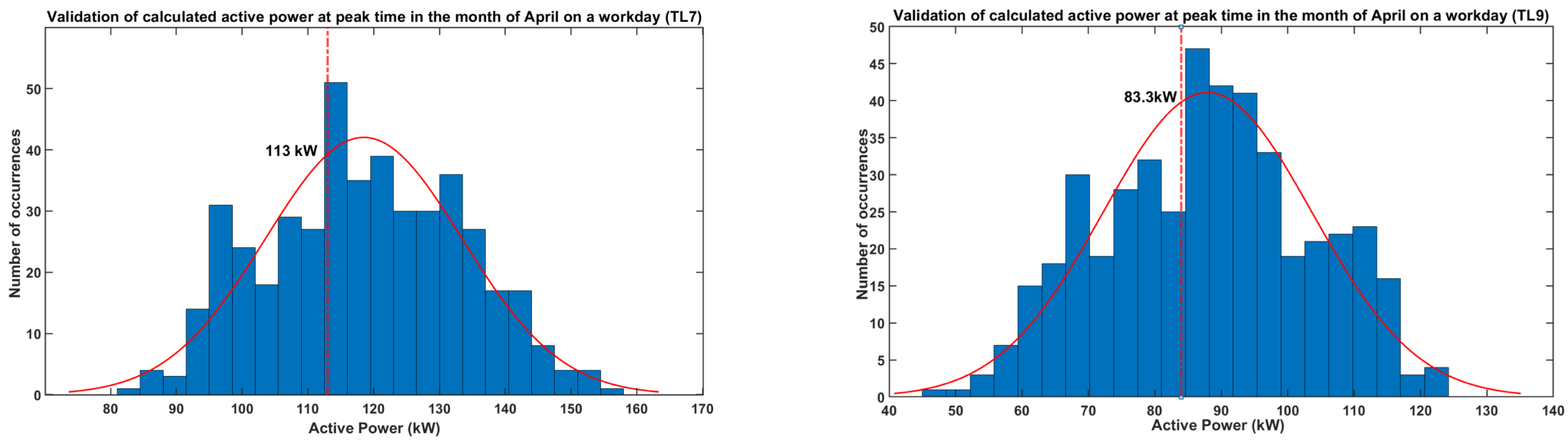


Figure 6. Validation of active power at peak time for Enexis BV network

## Results

### Enexis Network

- The determined values are close to the mean of all the values which are determined from the PDF approximations of stochastic LV power flow simulation results of Gaia as seen in Figure 6.

### Stedin Network

- Figure 7 shows the difference in results for the two scenarios.
- It shows that the type of input taken affects the accuracy of determined states.

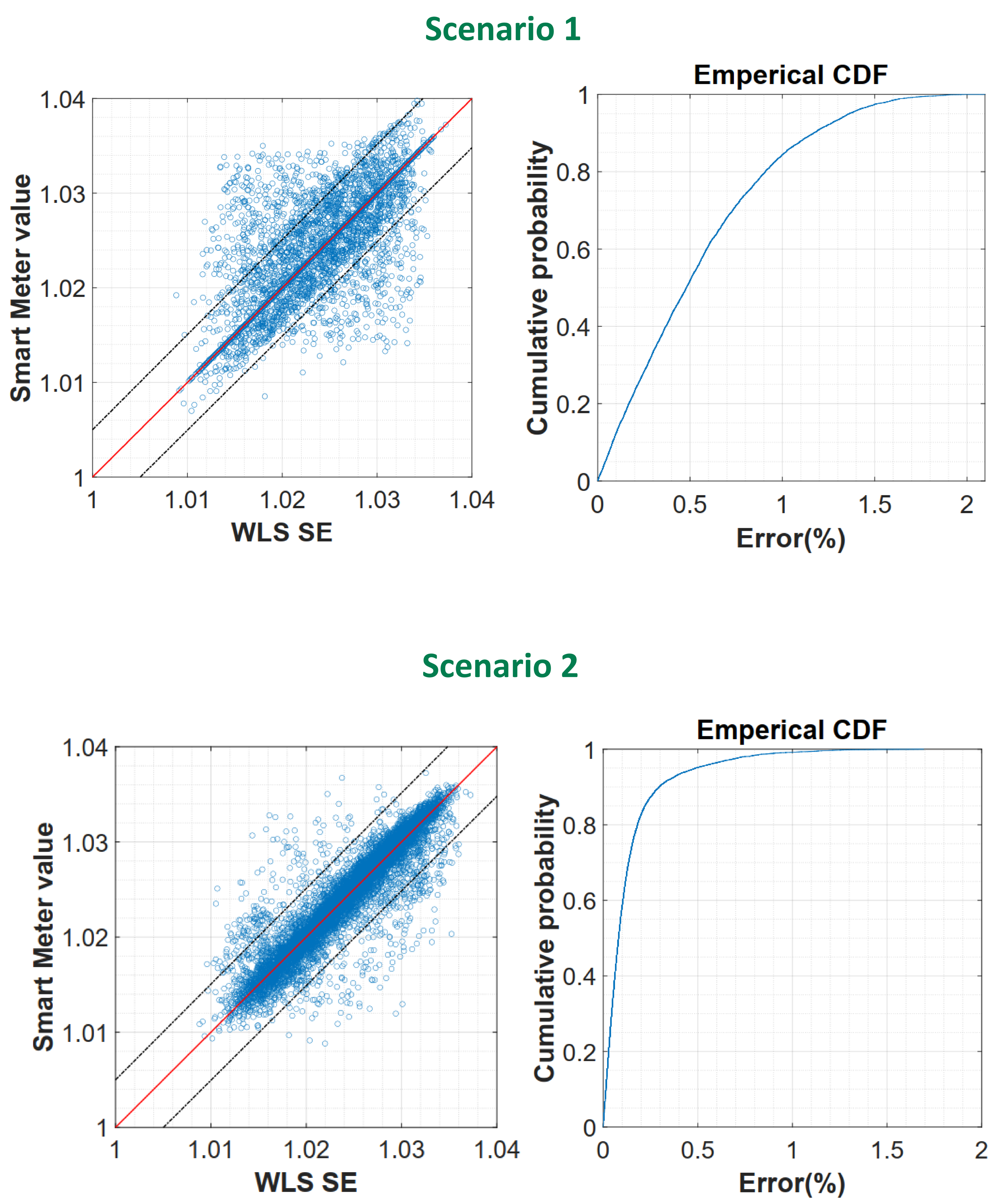


Figure 7. SE result comparison scenarios for Stedin BV network

## Conclusions/Discussions

- The working of WLS algorithm on the networks using synthetic data and measuring devices data is verified.
- The effect of type of input measurement on state estimation precision has been evidently demonstrated.
- A detailed way of generating pseudo-measurements for the nodes with missing data is proposed, and a validation with available data is done.

## References


- F. Schweppe and J. Wildes, "Power system static-state estimation, part i: Exact model," *IEEE Transactions on Power Apparatus and Systems*, vol. PAS-89, no. 1, pp. 120–125, Jan. 1970, ISSN: 0018-9510.
- A. Abur and A. Gómez Expósito, *Power system state estimation: theory and implementation*, ser. Power engineering. New York, NY: Marcel Dekker, 2004, 327 pp., ISBN: 978-0-8247-5570-6
- Nibhanupudi, S.S., "*State Estimation in Medium Voltage Distribution Networks*". Available: http://resolver.tudelft.nl/uuid:b6c10f50-3e5c-454b-8f6c-2f0cb31688c7
- Phase to Phase – netten voor distributie van elektriciteit. (in Dutch). Available: https://phasetophase.nl/boek/index.html.


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