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ANN – Based Method for Enhancing State Estimation of Grids with High Penetration of Renewables

S. Cosic[1], I. Vokony[1]
[1] Department of Electric Power Engineering
Faculty of Electrical Engineering and Informatics
Budapest University of Technology and Economics

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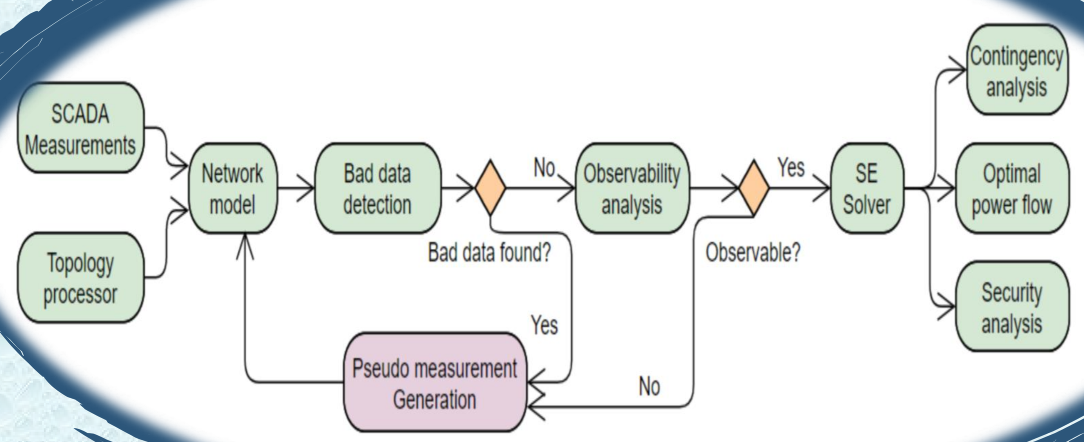
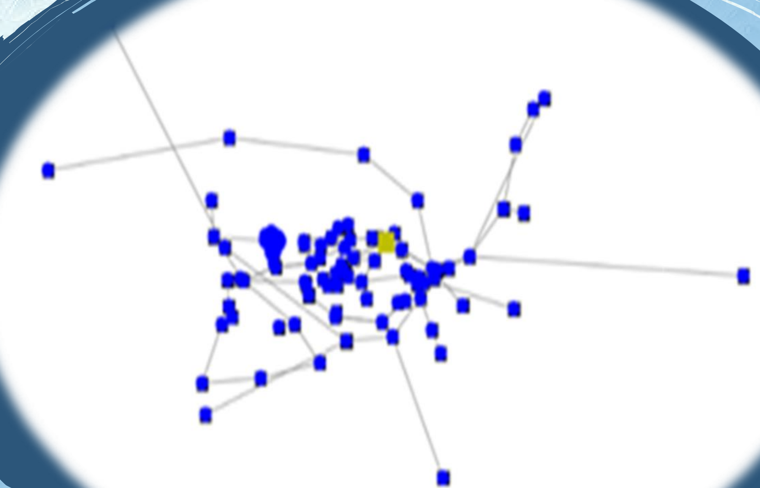
INTRODUCTION

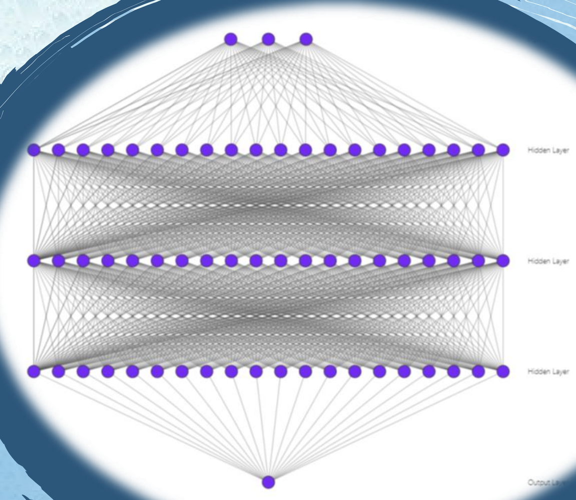
Contemporary power systems are facing a vast number of challenges in their pursuit for satisfying the requirements of security, equity, and sustainability. One of the major tasks in daily power system operation is maintaining the normal state, which heavily relies on the ability of supervisory control and data acquisition (SCADA) systems to continuously monitor the system through the acquisition of various measurements, their processing and determining the system state [1]. This process of inferring the values of system state variables using a limited number of measured data at certain locations is referred to as state estimation (SE) [2].

State estimation is well-established at the transmission system level, where it has been in use for the last few decades and is a most vital component of energy management systems [3]. However, distribution system state estimation still faces many challenges due to several issues [4], such as complex network topology, low X/R ratio, measurement scarcity, renewable energy penetration, unbalanced operation, communication issues etc. The aforementioned problems lead to distribution grids being essentially unobservable.

This paper suggests an approach to offset the poor observability and achieve accurate state estimation by using ANN in the pseudo/measurement generation process, as well as utilizing an alternative SE algorithm and a nonconventional estimator for better robustness.







PROPOSED METHODOLOGY

ANN for Pseudo-Measurement Generation

A three hidden layer feed-forward ANN topology, demonstrated in Fig. 2, which takes historical load active and reactive power data, together with static generators' profiles as inputs and 200 neurons in each layer to train the network to successfully predict bus voltages as the output. The obtained data is then used as pseudo measurements to account for missing measurement data in the dynamic state estimation process.

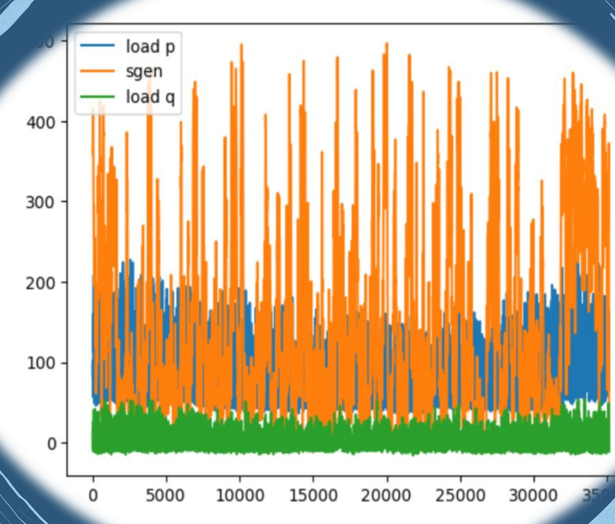
The data set consists of one-year load and static generator data in 15-minute resolution, adding up to 35136 time steps, out of which 25% (8784) were used in the training set, and the rest was used in the validation set. The logistic sigmoid function was set as the output activation function, while stochastic gradient-based optimizer "Adam" was used as a solver.

Iteratively Reweighted Weighted Least Squares

IRWLS algorithm assumes that a robust signal recovery can be achieved by global minimization of the sparse vector of sensing data by solving a least-square problem in each iteration. However, it is capable of adjusting several constraints from active to inactive in one iteration by using only certain samples, thus using only a portion of the kernel matrix, which significantly decreases the run-time complexity.

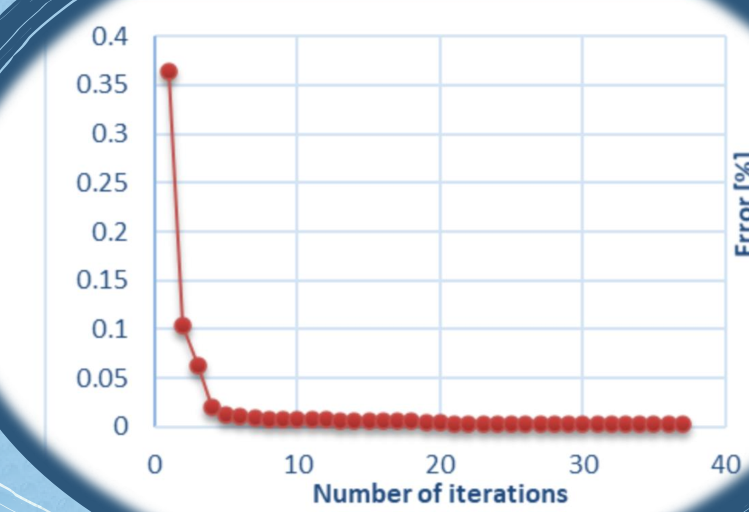
Schweppe-Huber Generalized Max Likelihood Estimator

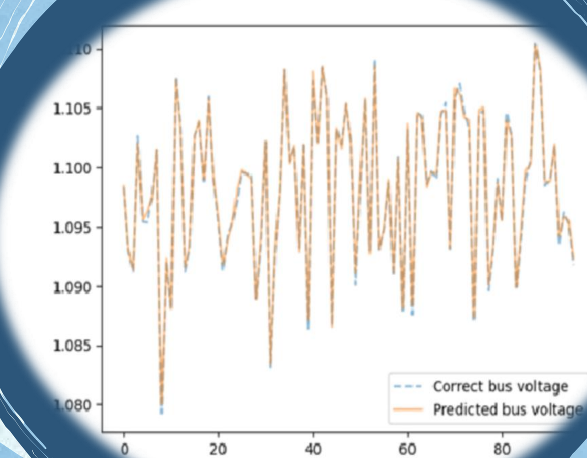
In poorly observable networks subject to topology errors and frequent load changes, the conventional estimator may yield highly biased state estimates or suffer from divergence problems. To overcome these issues, this paper suggests an estimator whose SHGM Likelihood estimator, whose statistical and numerical robustness have been proven.

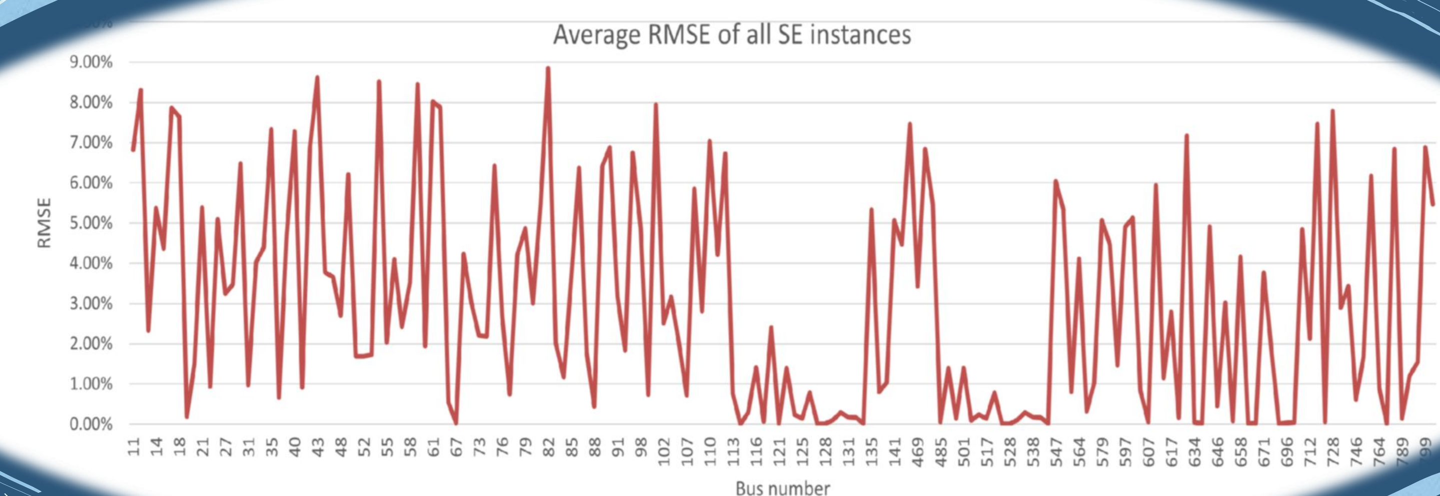


RESULTS

Research issue	Proposed methodology	Achieved results
Lack of system observability due to low measurement redundancy	Pseudo measurement generation by using Artificial Neural Networks (ANN)	Remarkable efficiency improvement, fixed observability issue
Low robustness against bad data	Iteratively Reweighted Least Squares algorithm	Faster convergence, improved computational efficiency
Highly biased state estimates, solution divergence problems	Modified Schweppe-Huber Generalized Maximum Likelihood estimator	Full convergence for all time instances, improved accuracy







TEST GRID

TYPE	NO OF ELEMENTS
Transformer	5
Static generator	232 (212 PV, 1 hydro, 19 wind)
Bus	514
Switch	802
Load	218

LITERATURE

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[4] K. Dehghanpour, Z. Wang, J. Wang, Y. Yuan, and F. Bu, "A survey on state estimation techniques and challenges in smart distribution systems," IEEE Transactions on Smart Grid. 2019, doi: 10.1109/TSG.2018.2870600.
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For the full list of literature, please refer to the paper.