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# Impact of line length, EV and PV on LV Grid topology identification based on voltage correlation

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## ABSTRACT

Grid operations and planning requires proper knowledge of the network topology, often lacking:

- meter to distribution transformer
- meter to feeder / phase within a transformer.

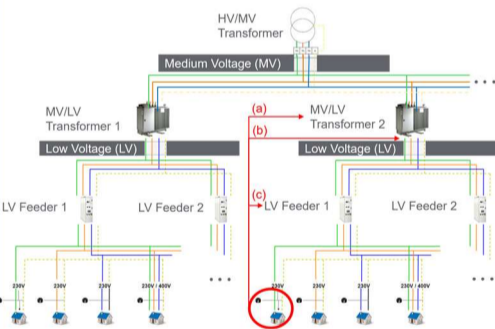
The paper presents a deep dive on a topology identification algorithm based on smart meters voltage data correlation only, avoiding the installation of additional sensors.

Performance is evaluated on several simulated network configurations with realistic grid models. Sensitivity to three major factors – line length, Electrical Vehicles and Photovoltaic systems – is analyzed in the perspective of real-world deployment.

## 1. INTRODUCTION

This paper uses a method based on classic voltage correlation methods to identify LV Grid topology :

- Meter to feeder (b)
- Meter to phase (c)



The method was applied to sets of simulated data to assess its robustness, variability and ensure its scalability.

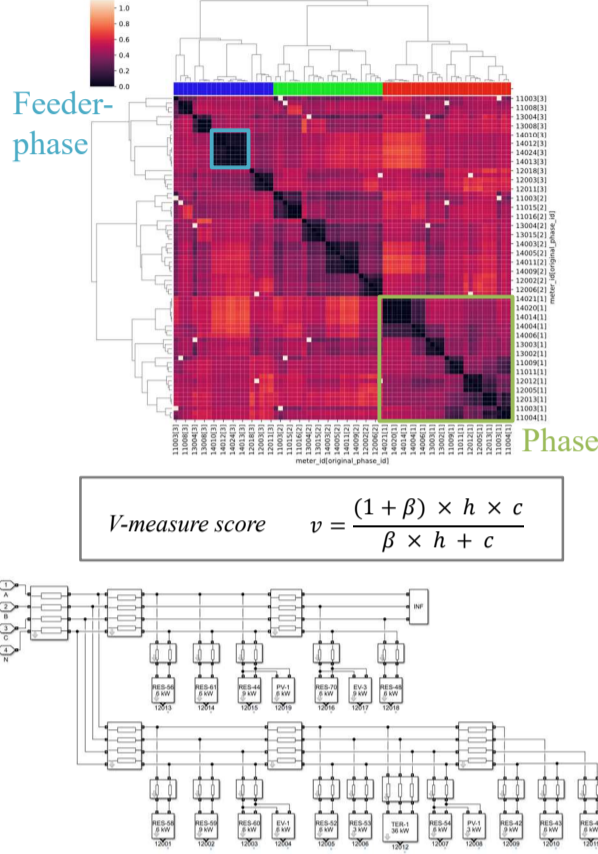
## References

[7] A. B. Pengwah, L. Fang, R. Razzaghi and L. L. H. Andrew, "Topology Identification of Radial Distribution Networks Using Smart Meter Data," in IEEE Systems Journal, vol. 16, no. 4, pp. 5708-5719, 2022.

[11] A. Rosenberg and J. Hirschberg. "V-Measure: A Conditional Entropy-Based External Cluster Evaluation Measure". 410-420. Proceedings of the 2007 Joint EMNLP-CoNLL conference, pp. 410-420, Prague, Czech Republic, 2007.

## 2. METHODS

- Calculate the correlation between each pair of voltage time series. Several configurations of sampling, normalization and correlation metrics are used.
- A clustering algorithm is then applied to partition meters into the  $k$  most intra-correlated and least inter-correlated groups of time series.
- Test topologies generated by configurable model of LV network: cable's length, type of consumers, EV & PV penetration.
- Urban and a rural MV/LV distribution networks.



$$V\text{-measure score } v = \frac{(1 + \beta) \times h \times c}{\beta \times h + c}$$

## 3. RESULTS

Figure below shows V-measure for meter to feeder-phase (Top) and phase (Bottom) for the rural, 75 meters, transformer. Results are shown by cable lengths, and insertion of EV, PV in the topology. Boxplots and dots represent distribution of score depending on parameters of the algorithm. Cross validated best set of parameters is highlighted in red.

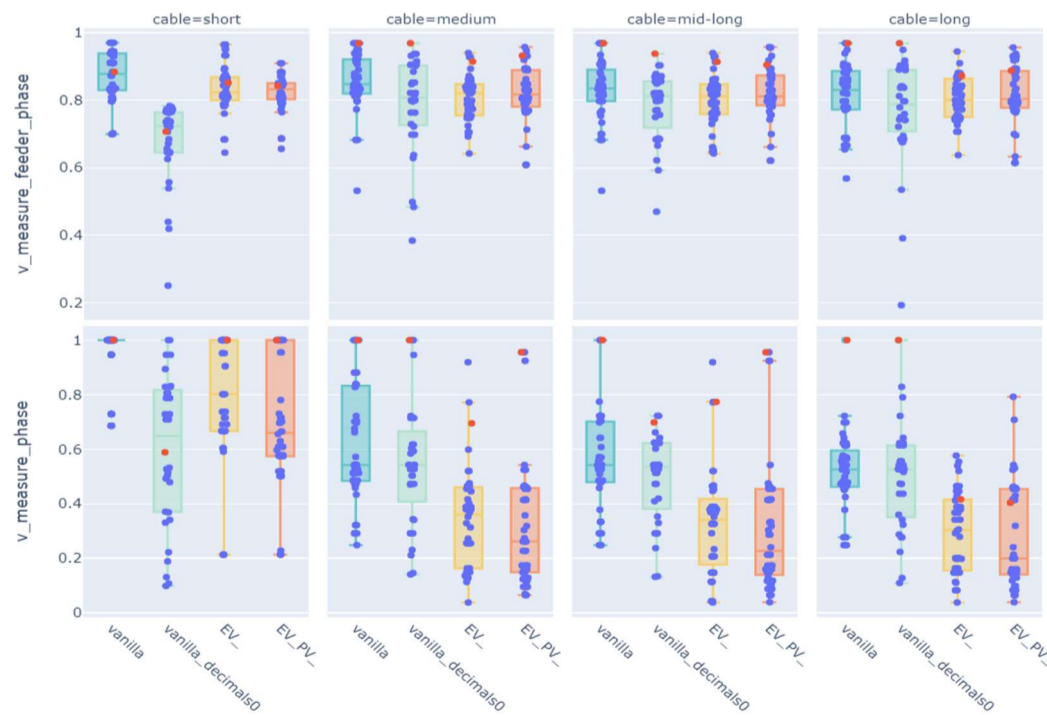
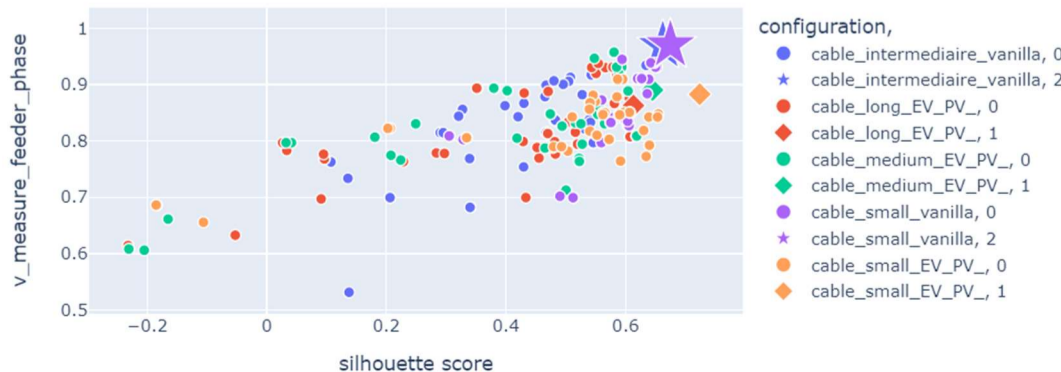


Figure below represents V-measure in function of silhouette score for meter to feeder-phase. For several configurations in colors, a diamond represent point with highest silhouette score, and a star when the highest silhouette score corresponds to highest V-measure.



## 4. CONCLUSIONS

Grid configurations impact more meter-to-phase than meter-to-feeder-phase. The phase signal is gradually lost depending on the following parameters :

- Increasing number of consumers is challenging for identification as V-measures for transformer with 10 customers are close to 1.0 in all situations.
- Phase clustering is more sensitive to cable length. The explanation is that longer cables yield to greater impedance that hinder phase signals.
- EV and PV introduction impacts greatly the phase clustering performances as those charges change the active-reactive power, hence voltage, locally.
- Lower numerical precision impacts algorithm performances. However, best parameter set leads to scores above 0.7 in the extreme case of 1V precision.
- Maximizing the silhouette score tends to maximize the V-measure. Leading to a way to predict the quality of the clustering.

On all variations studied, only high EV and PV penetration shows intense performance drop that could hinder the method scalability.

Future studies will focus on assessing the performances on more simulated topologies and real measurements. Also, based on those results, an algorithm for feeder clustering is under development.

## Contacts

