Topology Estimation from Voltage Edge Sensing for Resource-Constrained Grids

Mohini Bariya, Genevieve Flaspohler, Ngoran Clare-Joyce, Margaret Odero

*n*Line Inc.

nline.io

Outline

- **Motivation** - Why does the grid matter? Why does topology matter?
- **Methods** - The context of this work
- **Algorithm** - How do we estimate topology?
- **Case Studies** - How do our methods perform?

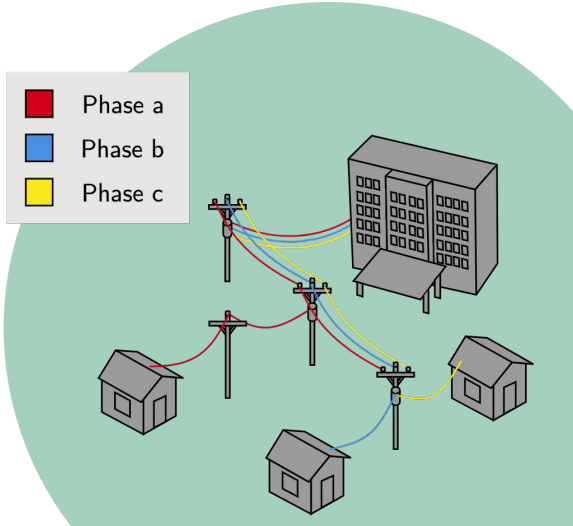
Electric grids are critical but challenged

- Electric grids are central to climate change's *twin challenge:* **decarbonizing energy production** & **meeting growing global demand**
- Successfully meeting this challenge requires more efficient operations, especially in low & middle-income countries (LMICs)
- Many issues arise in the low-voltage distribution network.
  - The majority of system losses
  - The majority of outages

Distribution grids are vast, convoluted networks.

Monitoring is essential

- Efficient grid operation demands knowledge of state, of which **topology (the network structure)** is a key piece.
- Topology *contextualizes* measurements within the physical network
- Topology information coupled with measurement can enable:
  - Targeting - Identify malfunctioning equipment, lossiest lines, phases with significant imbalance
  - Localization - Localize source of power outage, power quality issues
  - Awareness - Understand how power is flowing through the network



GridWatch - A practical grid monitoring approach

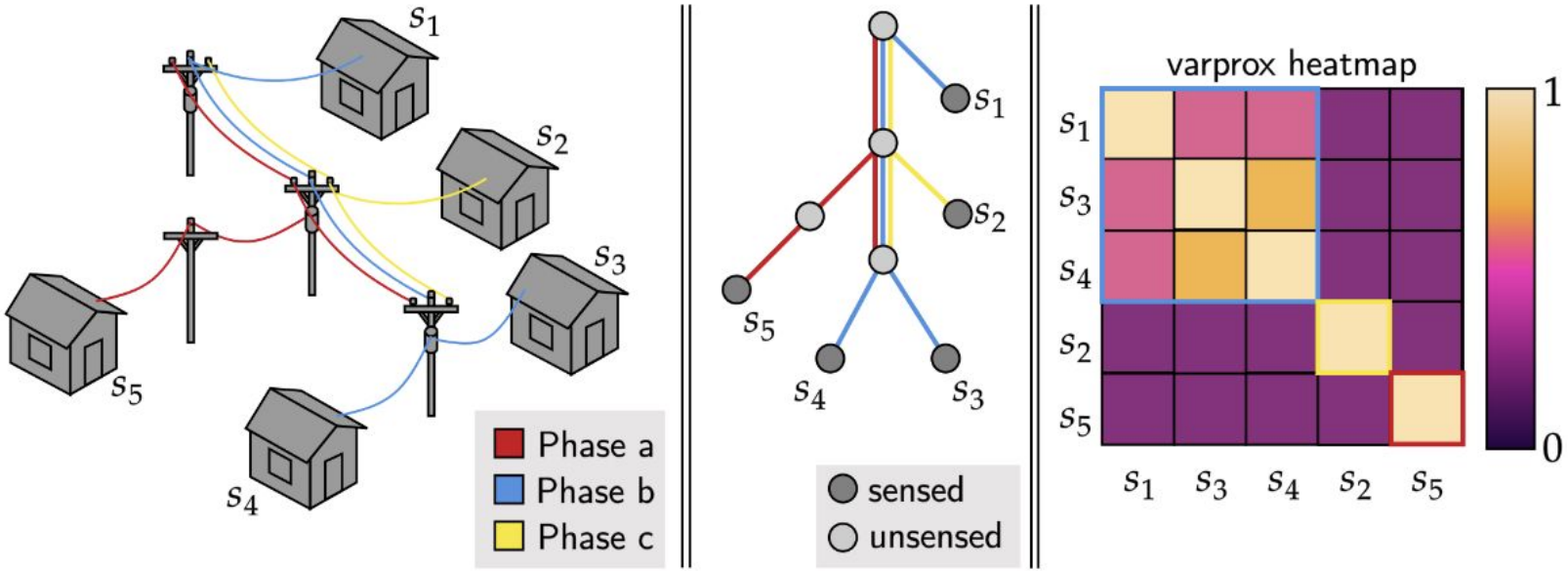
- Existing distribution monitoring is out-of-reach for LMICs
- *n*Lines's GridWatch is an affordable, flexible, scalable approach to distribution grid monitoring consisting of a fleet of **PowerWatch sensors**.
- Each PowerWatch sensor:
  - Plugs directly into a wall-outlet
  - Reports voltage magnitude, frequency, power state every two minutes
  - < 1% of PMU cost
- Sensor data is aggregated and transformed in cloud backend.

The Accra deployment

This study uses data from our Accra deployment:

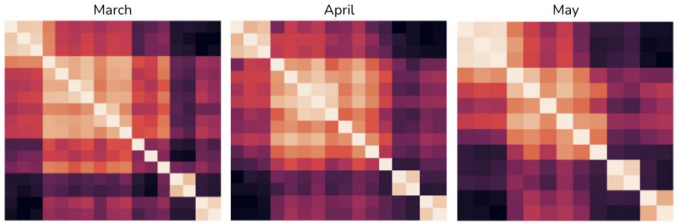
- 1,276 PowerWatch sensors
- Years of data
- Deployed for monitoring & evaluation of line-bifurcation project

Estimating Topology



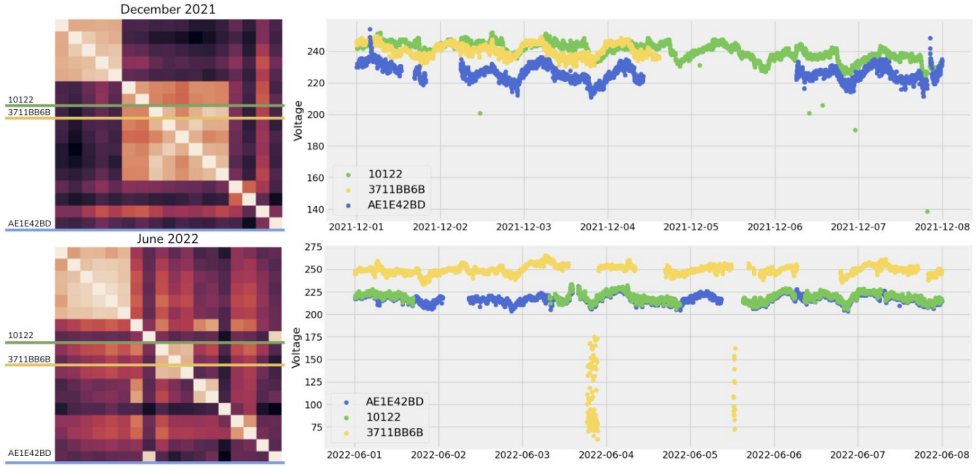
An example network topology (left) and corresponding algorithm result (right)

Case Studies



1

Consistency

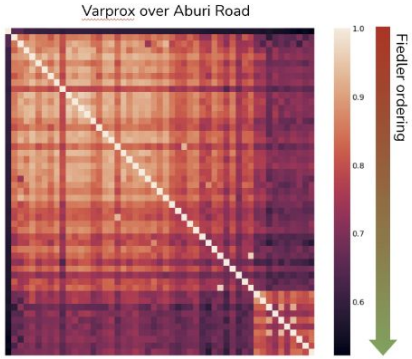


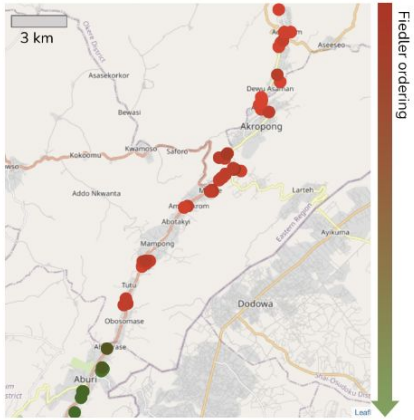
2

Distinctive changes reflecting network changes

3

Proximity over long distances

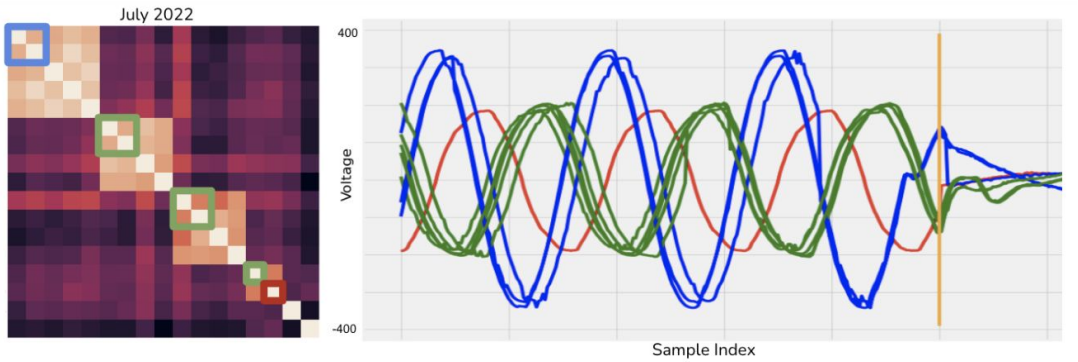




Summary & Next steps

This work presented initial results of topology estimation from a novel dataset: edge-sensed voltage magnitudes measured in an operational LMIC distribution system.

- Refine algorithms and extend with other data-types, for example: outages, voltage waveform snapshots, etc.
- Always open to collaboration! **mohini@nline.io**



Can waveform snapshots corroborate / bolster magnitude-based proximity?