

Sandia
National
Laboratories

Exceptional
service
in the
national
interest



U.S. DEPARTMENT OF
ENERGY



Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Vermont Regional Partnership: Facilitating the Effective Expansion of Distributed Energy Resources (The VT FEEDER Project)

Task 1: Parameter Estimation

Matthew Lave

Sandia National Laboratories

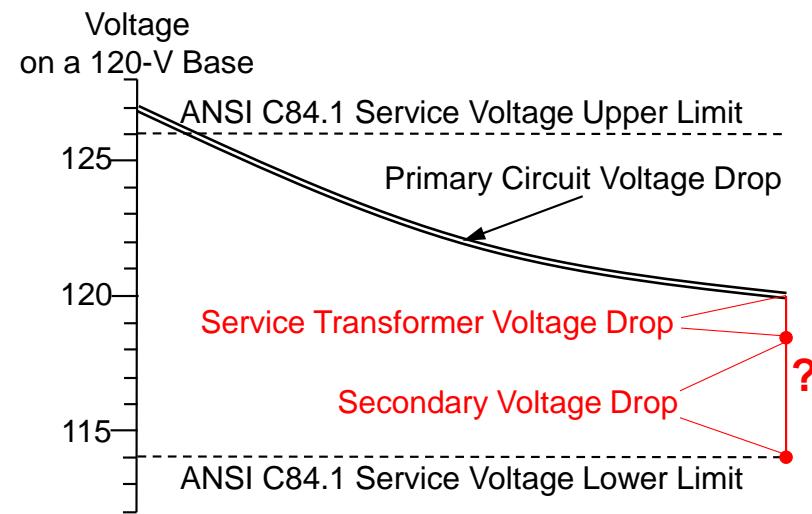
October 17, 2017

Task 1.1

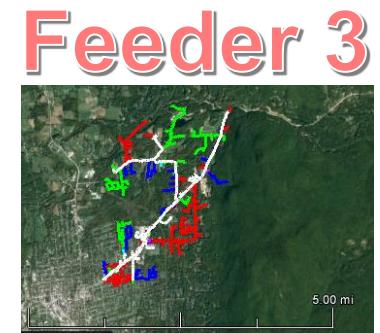
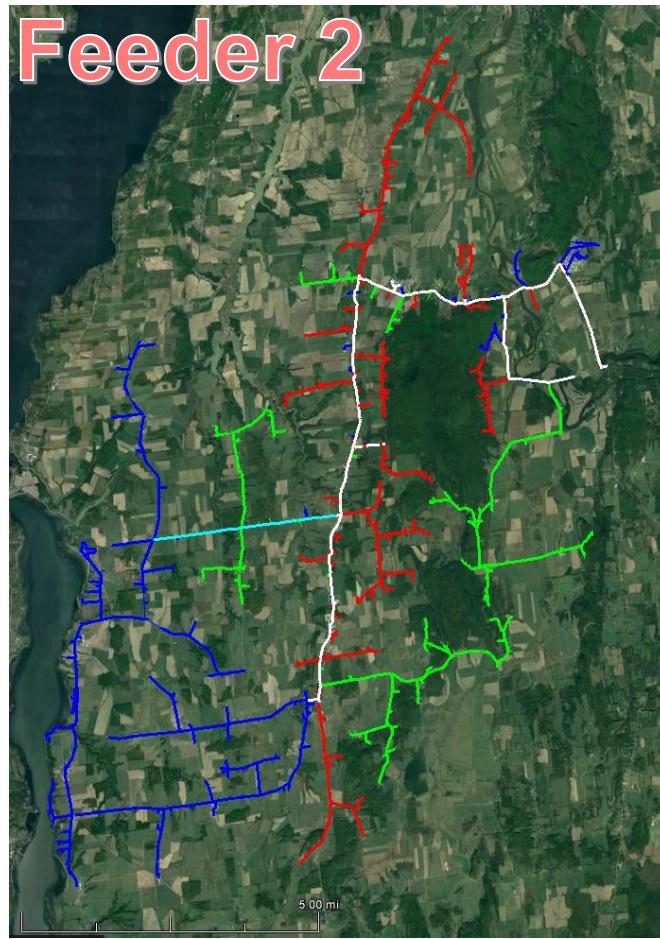
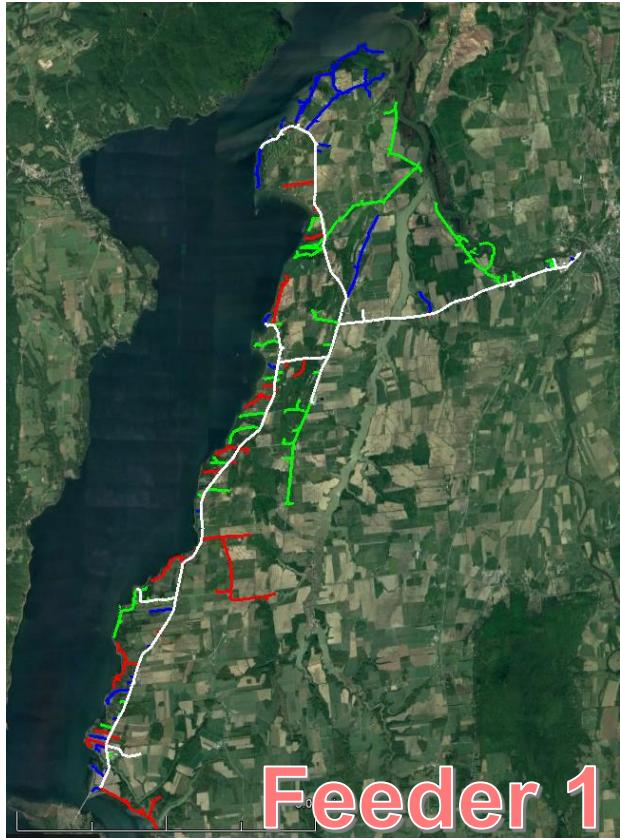
- **Distribution system parameter and topology estimation to improve distribution models**
- This task will implement an accurate, flexible, and computationally efficient method to use AMI measurement data to estimate secondary circuit series impedance parameters and topology in existing utility feeder models.
- The task will use AMI data to create accurate secondary system distribution models on 3 feeders in order to allow for more accurate hosting capacity analysis and feeder operation with ubiquitous distributed PV.
- The work in this task will consist of AMI data retrieval and cleaning, topology ID, and parameter estimation.

Need for Detailed Secondary Models

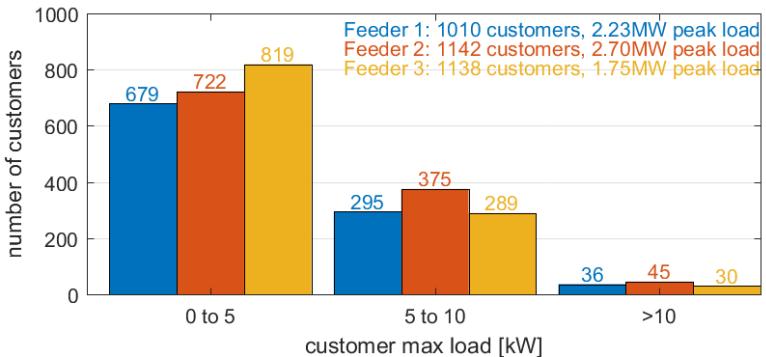
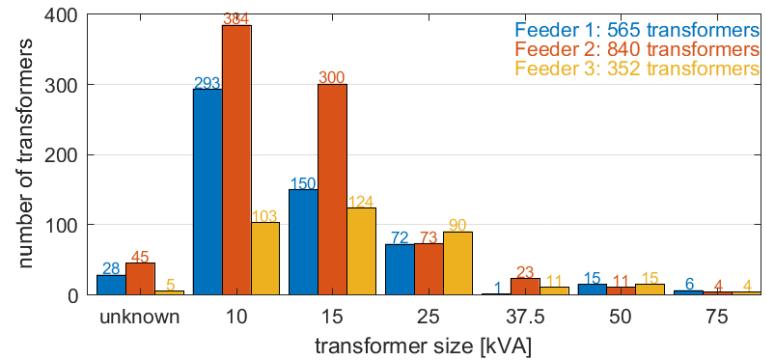
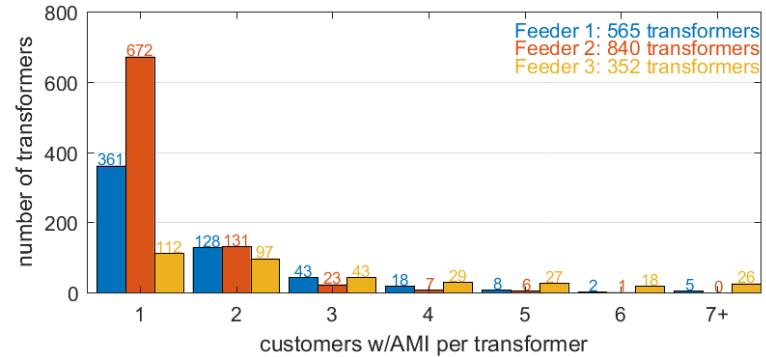
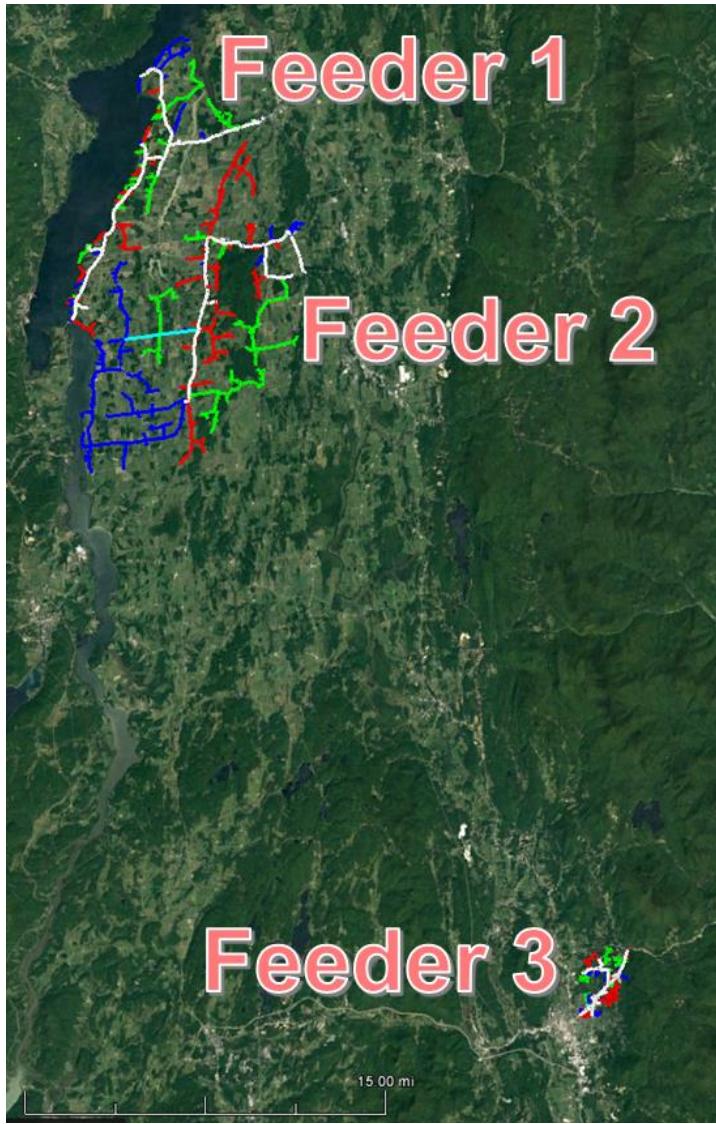
- Distribution system secondary (low-voltage) circuit models are typically not modeled or modeled with limited detail
- It is becoming important to have accurate secondary circuit models
 - A large number of DERs and sensors are connected to the secondary circuits
 - A large portion of the per-unit voltage drop/raise occurs over the secondaries
- Typical ways to enhance the GIS models
 - Manual inspections, utilizing added measurements, etc.
 - Require considerable man hours and extra resources ⇒ not cost-effective
 - May be hard to perform in urban areas with wiring underground and in buildings



Three feeders evaluated



Three feeders evaluated



Step 1

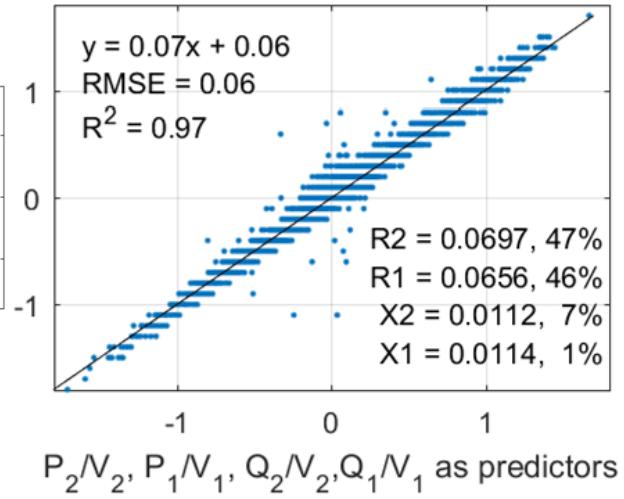
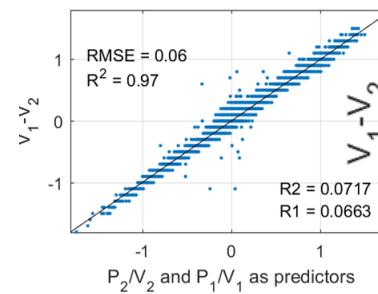
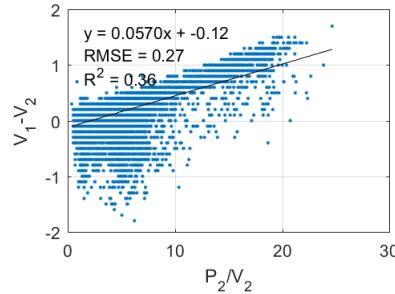
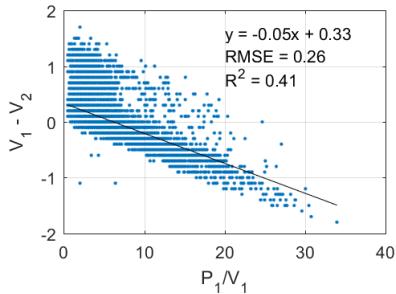
- For all customers on a transformer, find R_1, R_2, X_1, X_2

$$V_1 - V_2 = I_{R1}R_1 + I_{X1}X_1 + I_{R2}R_2 + I_{X2}X_2 + \epsilon$$

Known Unknown

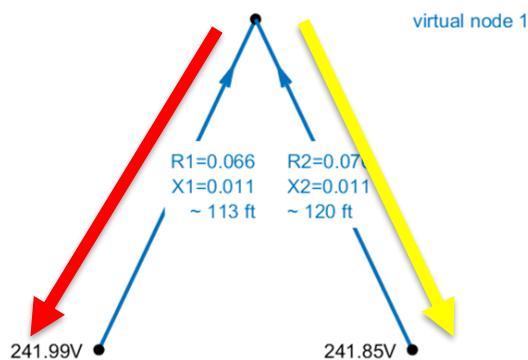
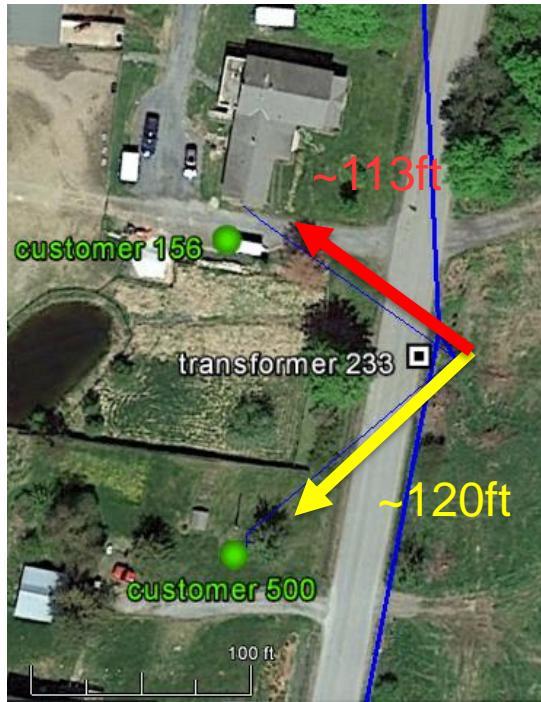
- Basic concept

- Fit R_1, R_2, X_1, X_2 values which best fit the V_1-V_2 fluctuations
- Note: R_1, R_2, X_1, X_2 are fit simultaneously;
figures below are only for illustration



- For comparison to satellite imagery
 - R values were used to compute a distance in feet of triplex cable, assuming $0.058\Omega/100\text{ft}$ (2/0 triplex)

Transformer 233 on Feeder 1

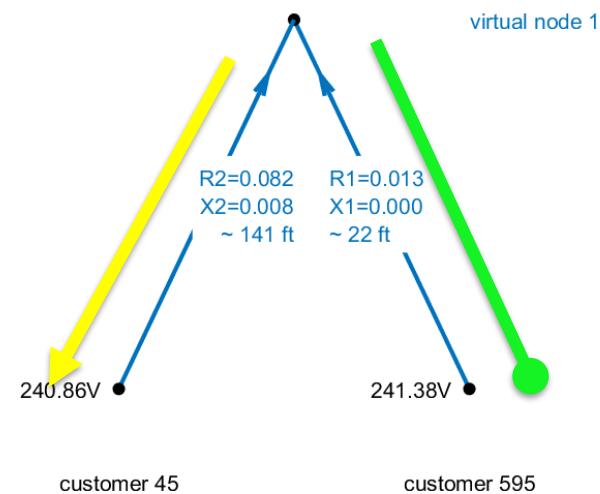


customer 156

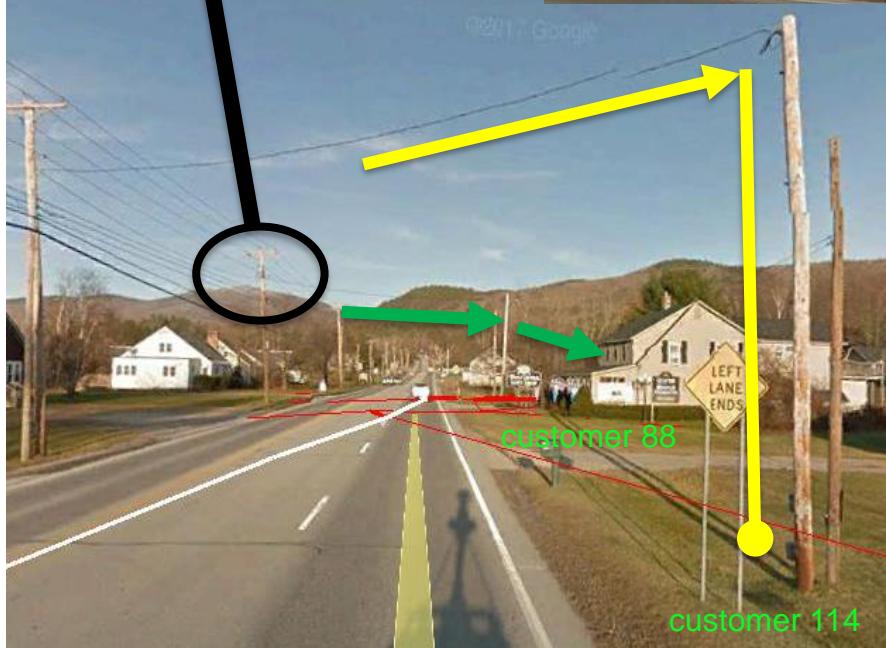
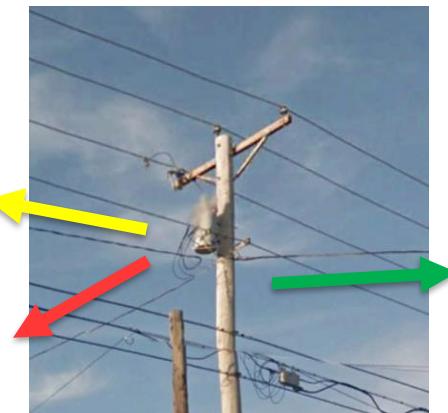
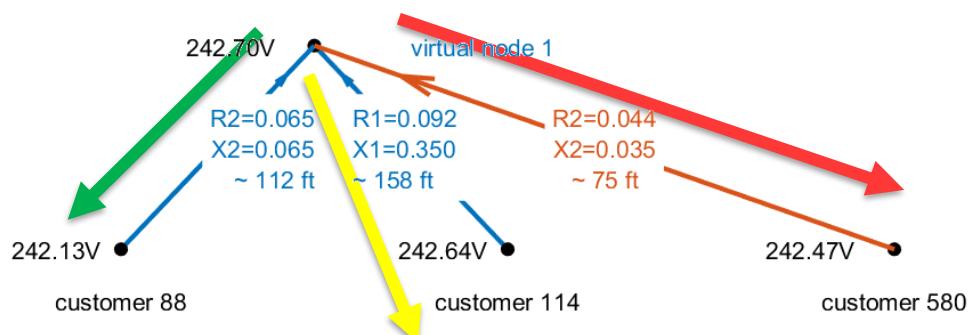
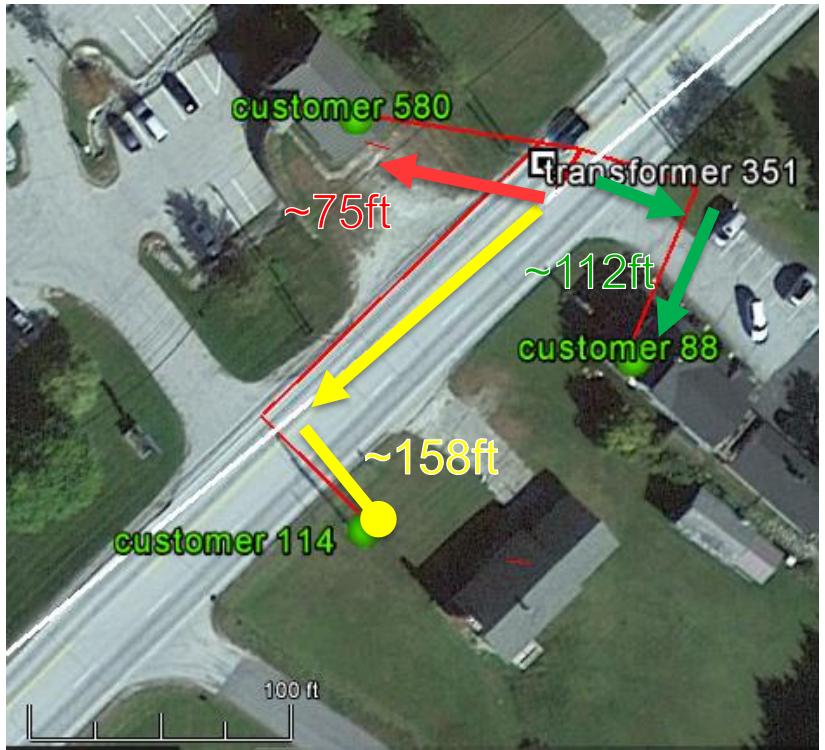
customer 500



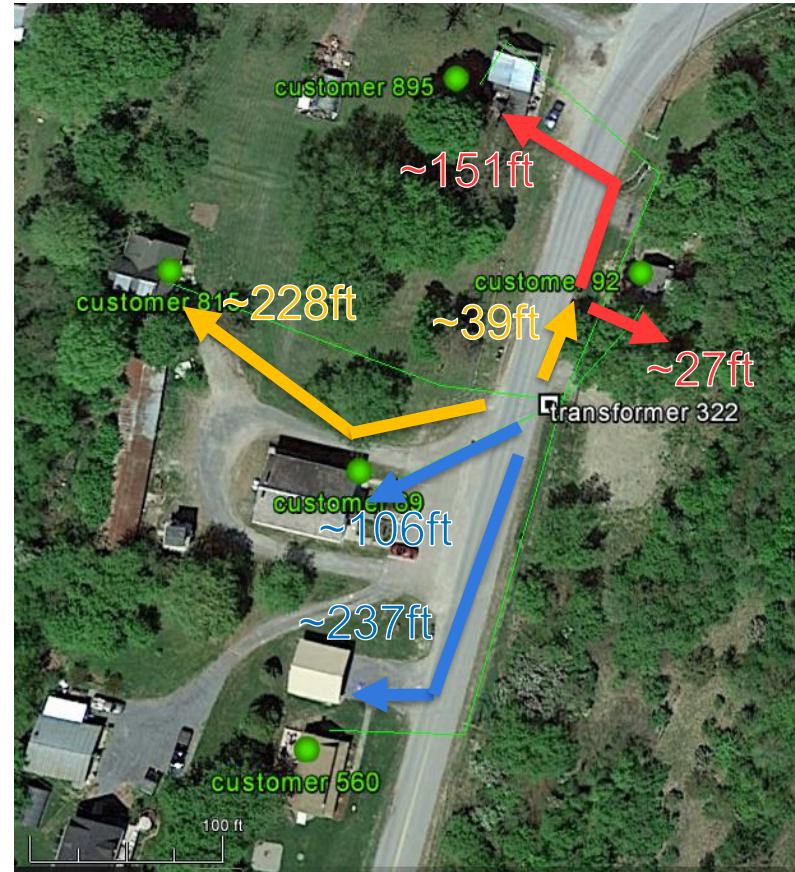
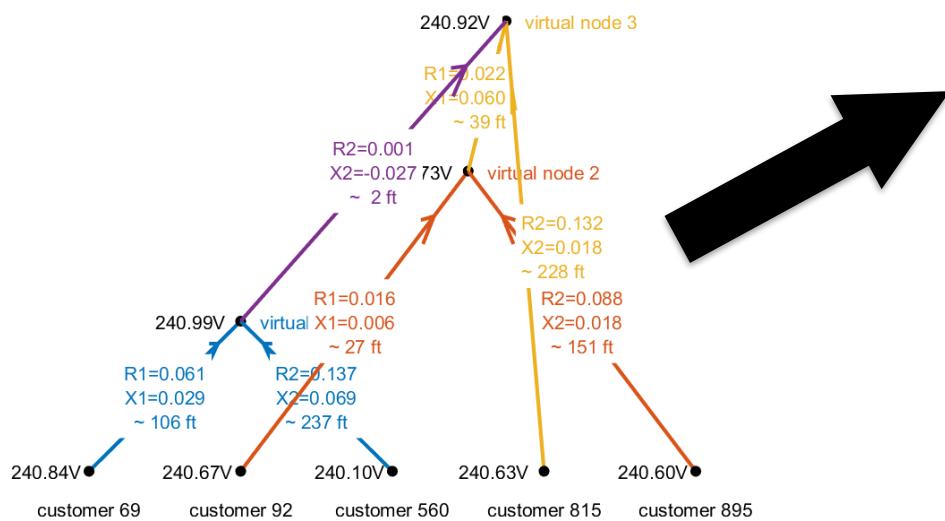
Transformer 301 on Feeder 2



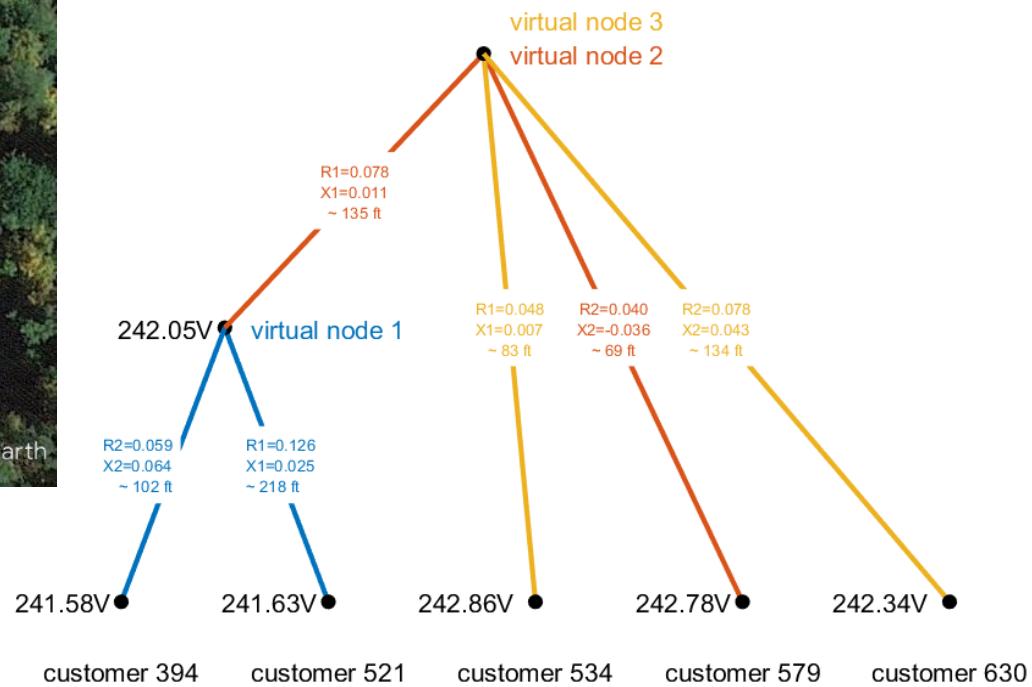
Transformer 351 on Feeder 3



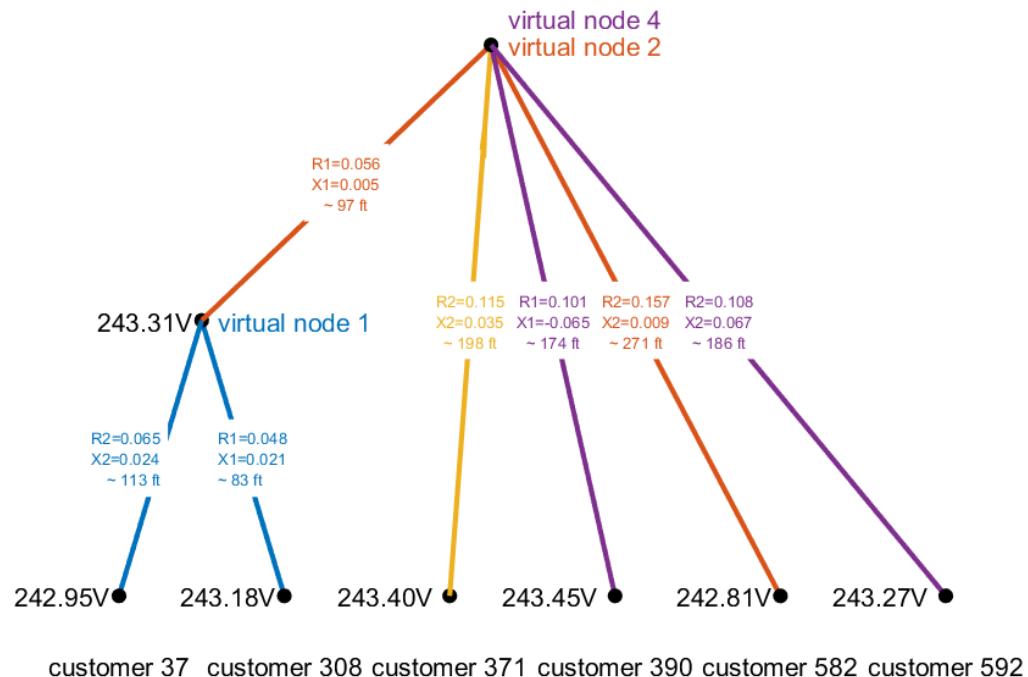
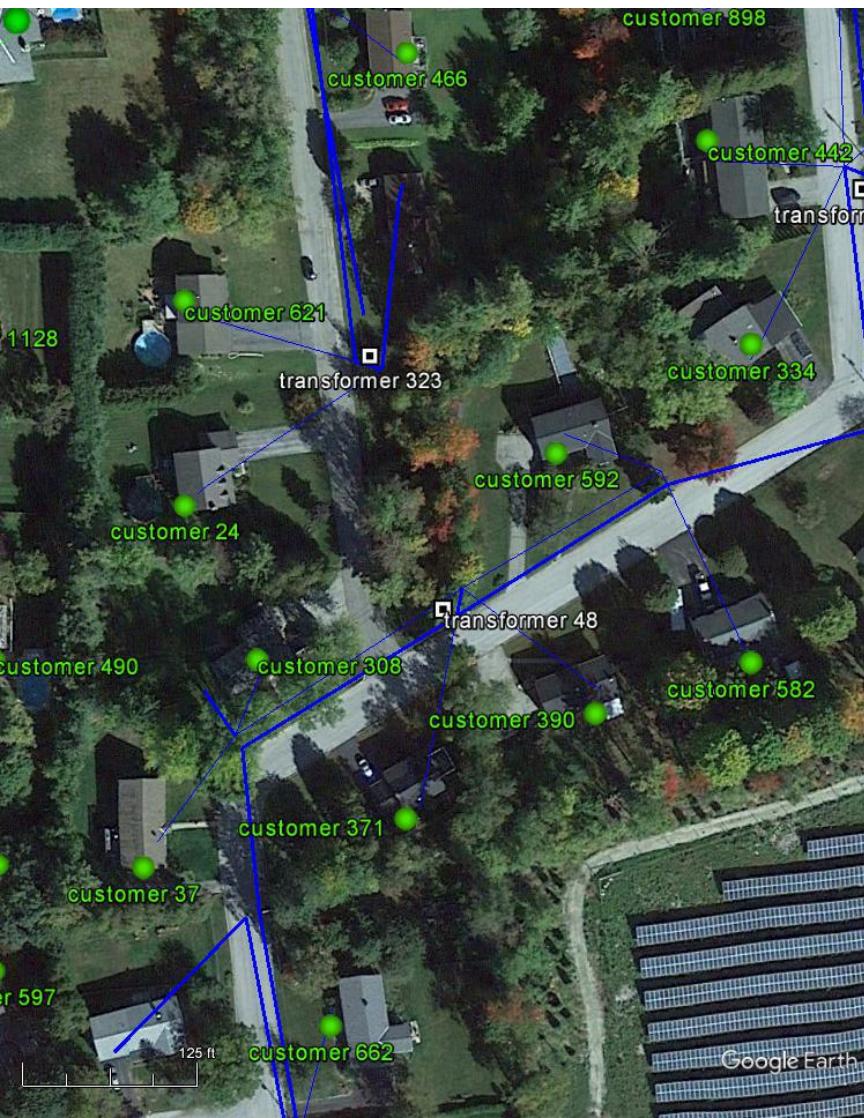
Transformer 322 on Feeder 1



Transformer 95 on Feeder 3



Transformer 48 on Feeder 3

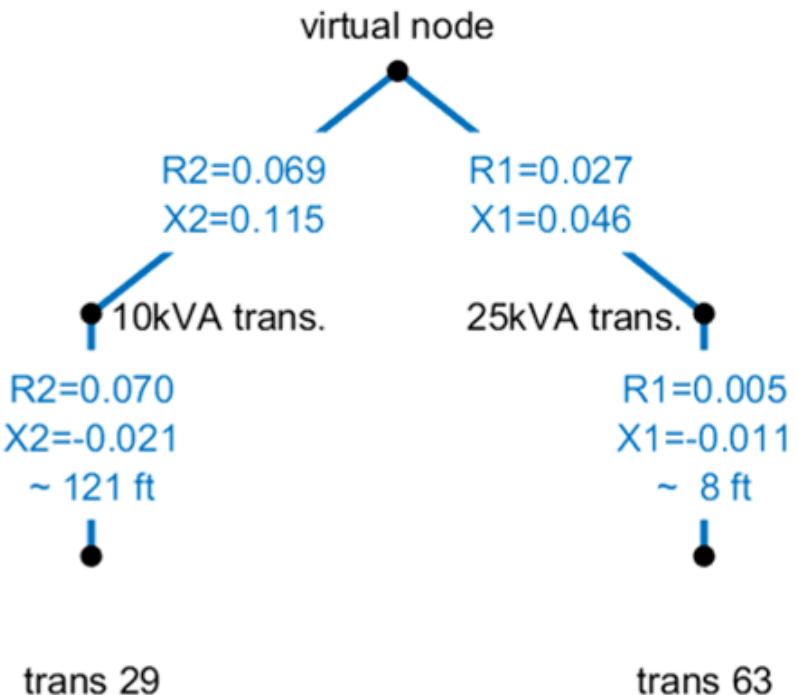


Step 2

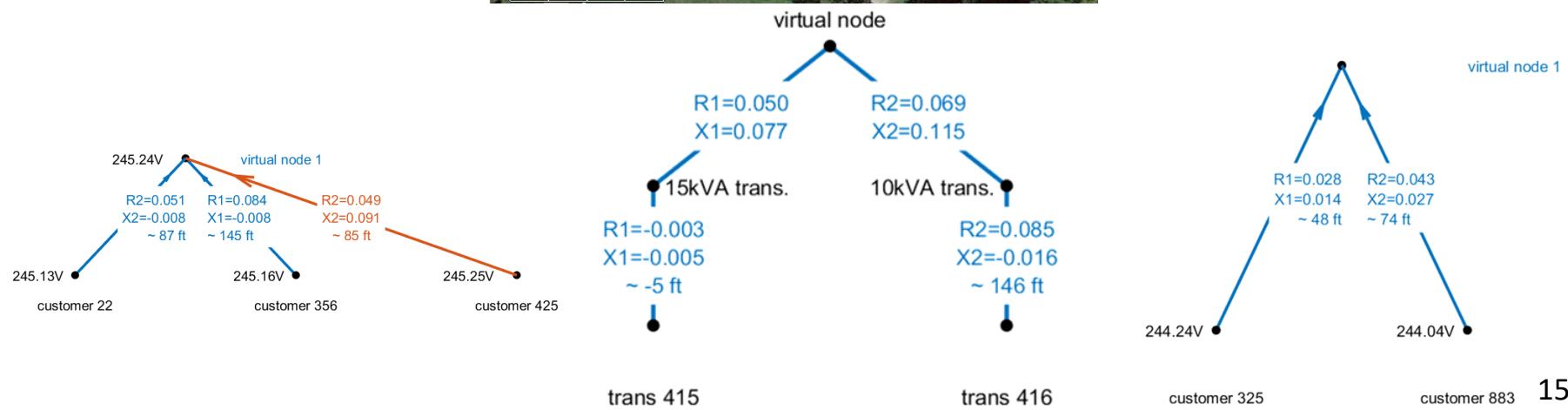
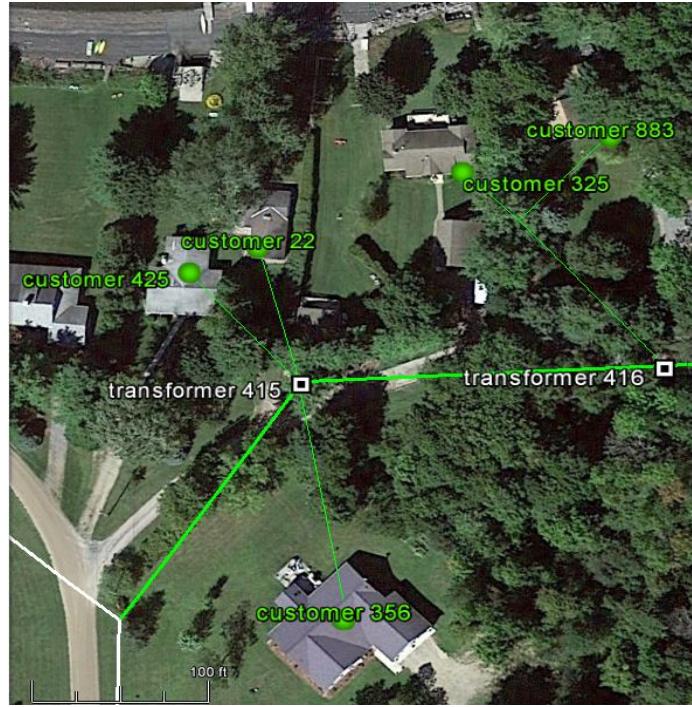
- Pair transformers with one another, run parameter estimation on virtual nodes created in step 1
 - Topology is always parallel – step 2 virtual node is on primary
 - Most likely scenario is that virtual node from step 1 is at transformer low side and any found impedance will be due to transformer impedance
 - In some cases, step 1 virtual node will be away from transformer
 - Serial connection between customers
 - Parallel connection that meets before the transformer
 - It is important to derive the additional impedance to fully resolve the secondary circuit

Transformer size (kVA)	3	5	10	15	25	37.5	50	75
Assumed resistance	1.5%	1.5%	1.2%	1.3%	1.16%	0.96%	1%	0.87%

Transformer 29 on Feeder 1

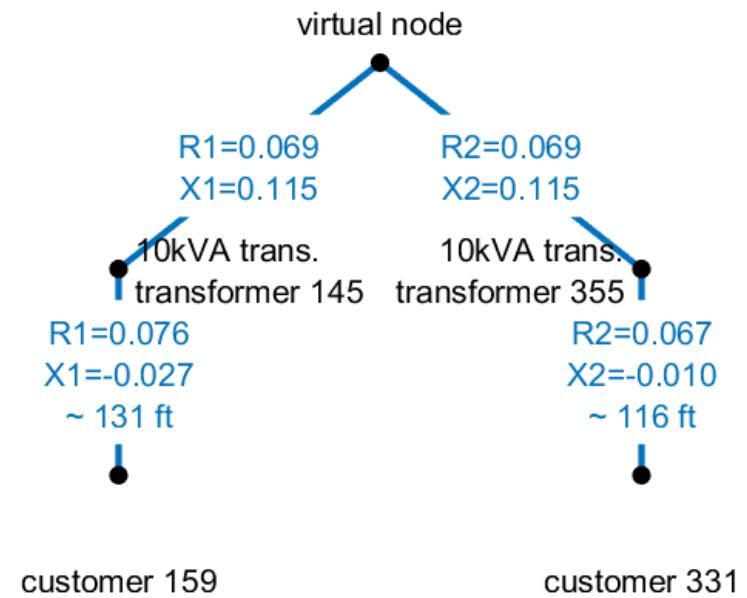


Transformers 415 and 416 on Fdr 1



Step 3

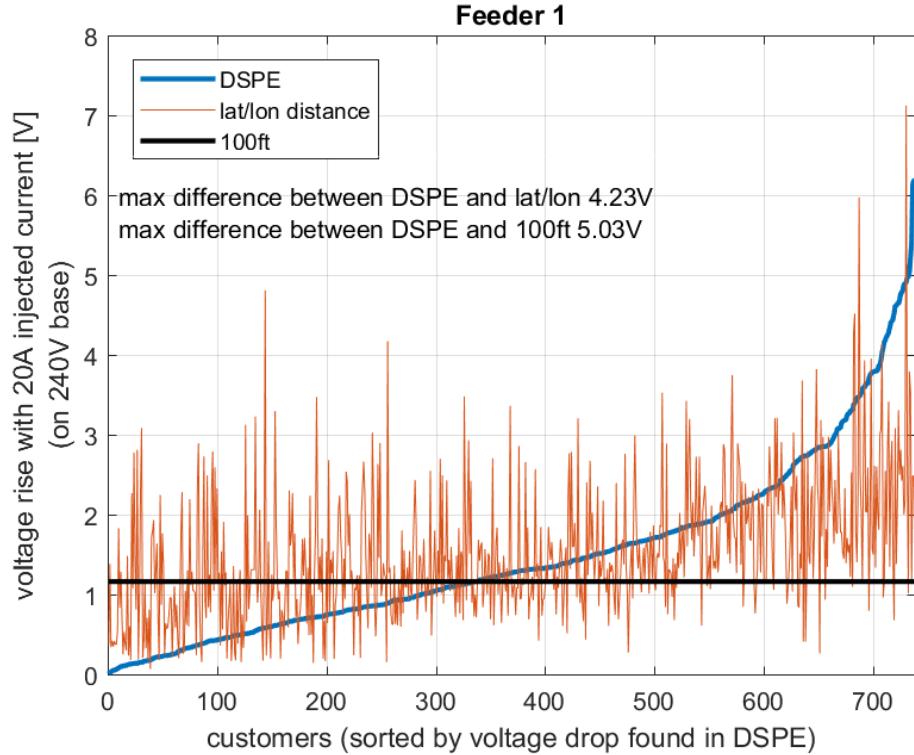
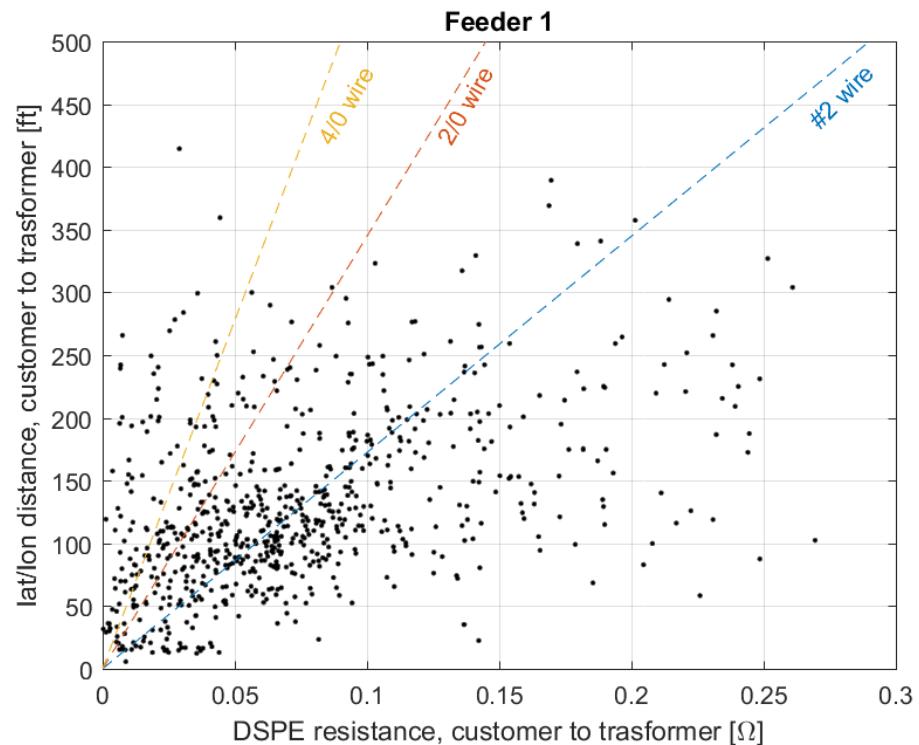
- Pair customers on transformers with only one customer with other solo customers
 - Topology is always parallel – step 3 virtual node is on primary
 - Should always be additional resistance beyond the transformer due to the customer being located away from the transformer



Notes on Entire Feeder Runs

- Ran all transformers with > 1 customer, all transformer pairs, and all single customer pairs for Feeders 1, 2, and 3
- Filtered out:
 - Customers with <1 week ($4*24*7$) of data
 - Customers with clearly errant voltage data (e.g., $>>1$ or $<<1$ p.u.)
 - Transformers with >7 customers (excessive run time)
- Compared to distances found from latitude/longitude
 - Several reasons why lat/lon distances may disagree
 - Customer location is wrong in lat/lon
 - Customer meter is not at same location as customer
 - Circuitous wire route

Feeder 1 Summary of Results



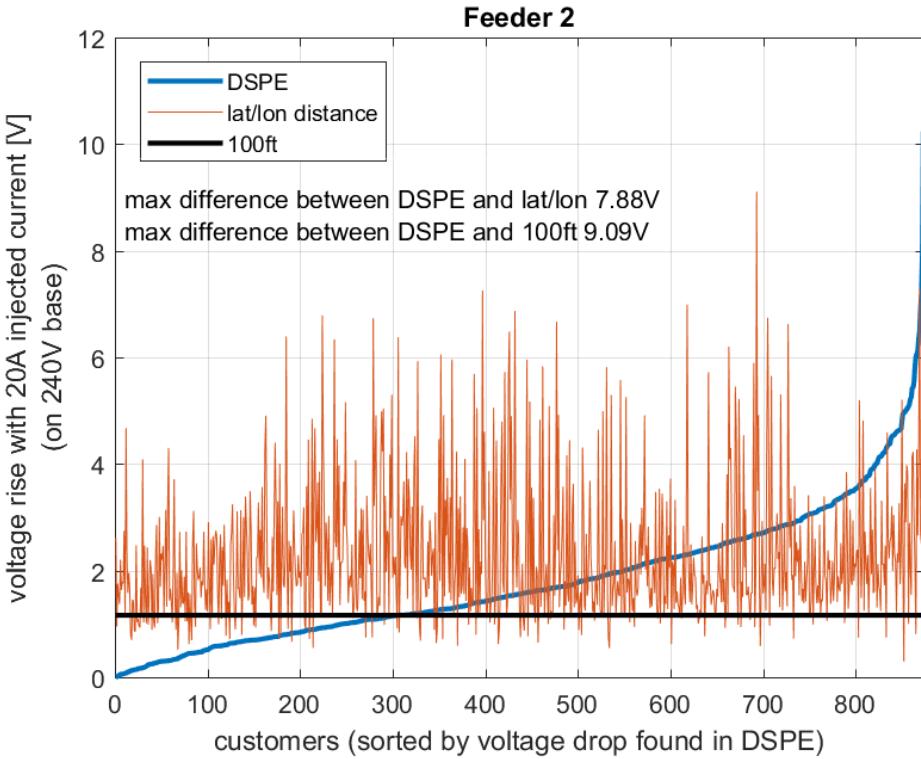
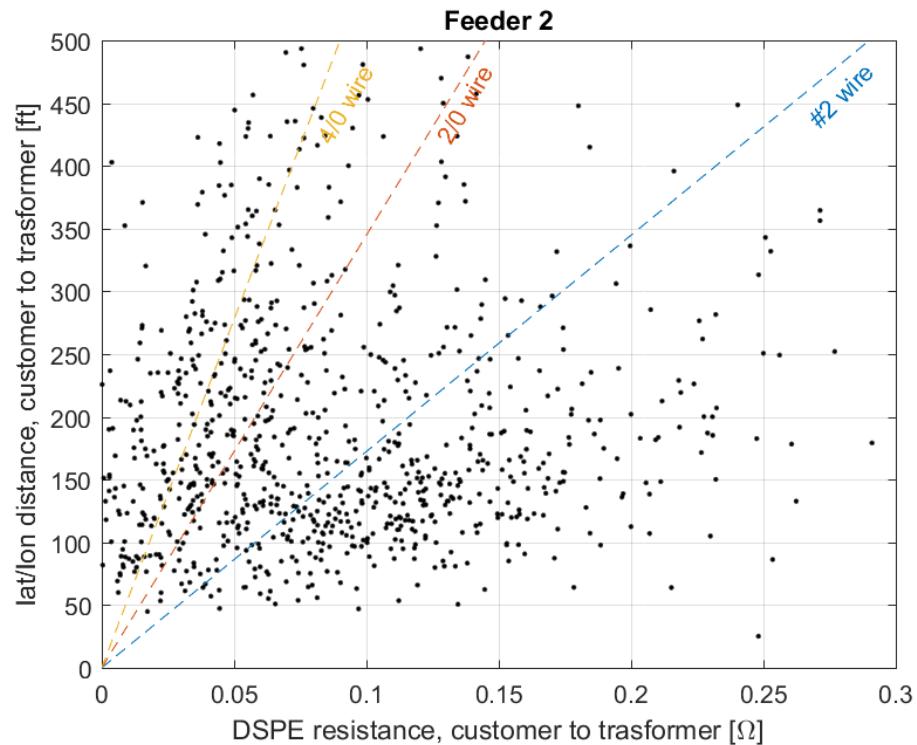
Reasons why PE > lat/ion (bottom right)

- Circuitous wire routing
- Lat/Ion at wrong location (e.g., at transformer)
- Wire higher resistance than assumed 2/0

Reasons why PE < lat/ion (top left)

- Meter closer to transformer than house (e.g., before wire goes underground)
- Lat/Ion at wrong location
- Wire lower resistance than assumed 2/0

Feeder 2 Summary of Results



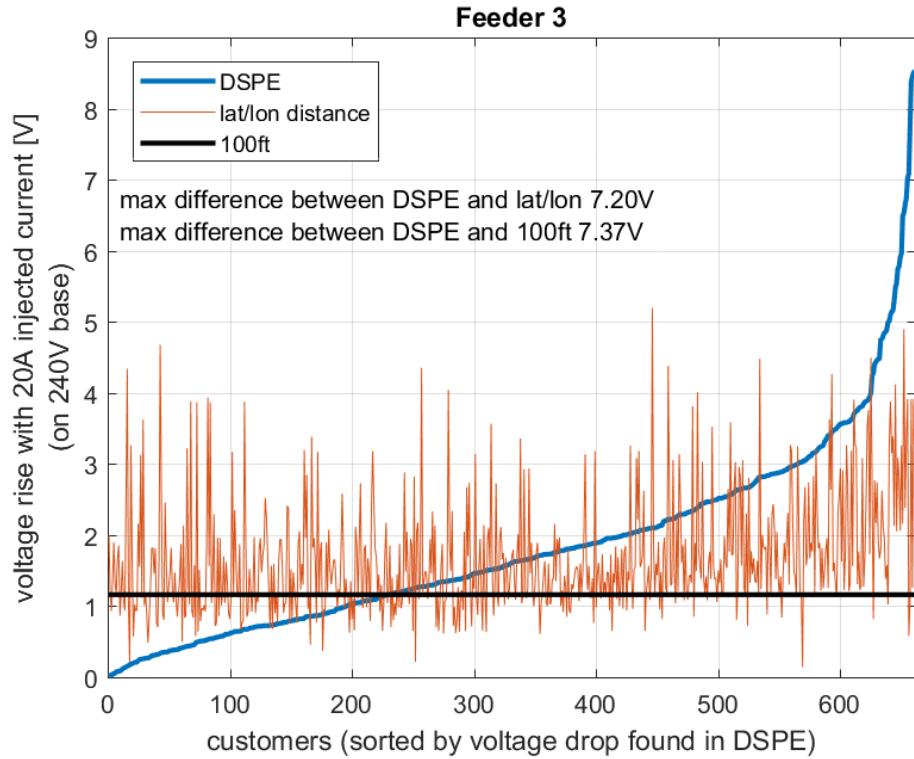
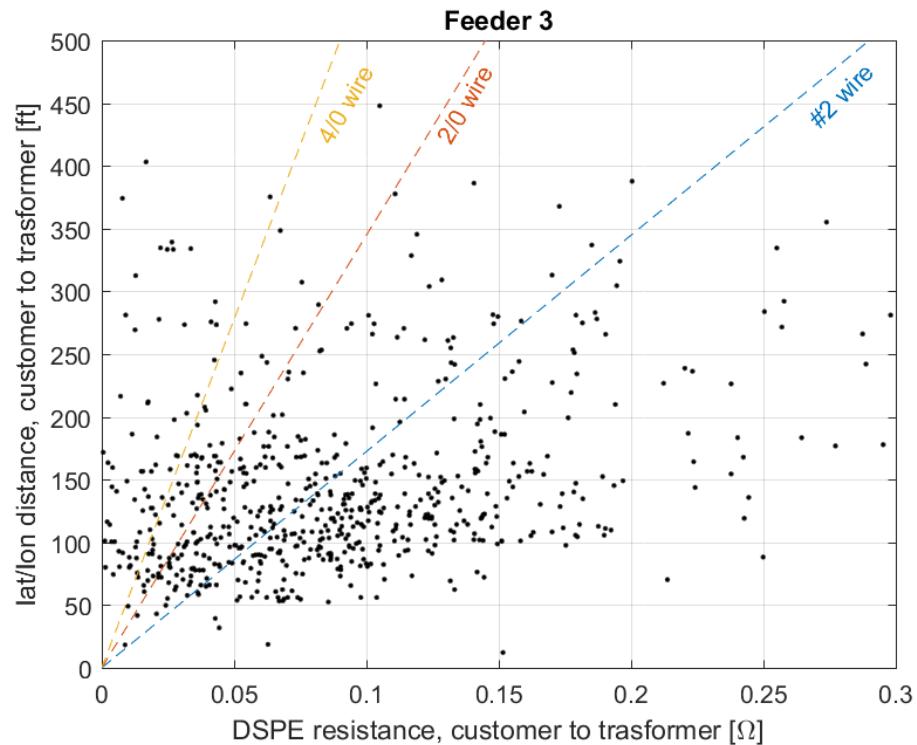
Reasons why PE > lat/lon (bottom right)

- Circuitous wire routing
- Lat/lon at wrong location (e.g., at transformer)
- Wire higher resistance than assumed 2/0

Reasons why PE < lat/lon (top left)

- Meter closer to transformer than house (e.g., before wire goes underground)
- Lat/lon at wrong location
- Wire lower resistance than assumed 2/0

Feeder 3 Summary of Results



Reasons why PE > lat/lon (bottom right)

- Circuitous wire routing
- Lat/lon at wrong location (e.g., at transformer)
- Wire higher resistance than assumed 2/0

Reasons why PE < lat/lon (top left)

- Meter closer to transformer than house (e.g., before wire goes underground)
- Lat/lon at wrong location
- Wire lower resistance than assumed 2/0