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Evaluating a Dynamic Line Rating Software Using Field-Measured PMU Data

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Charlotte, NC

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL is operated by Battelle for the U.S. Department of Energy

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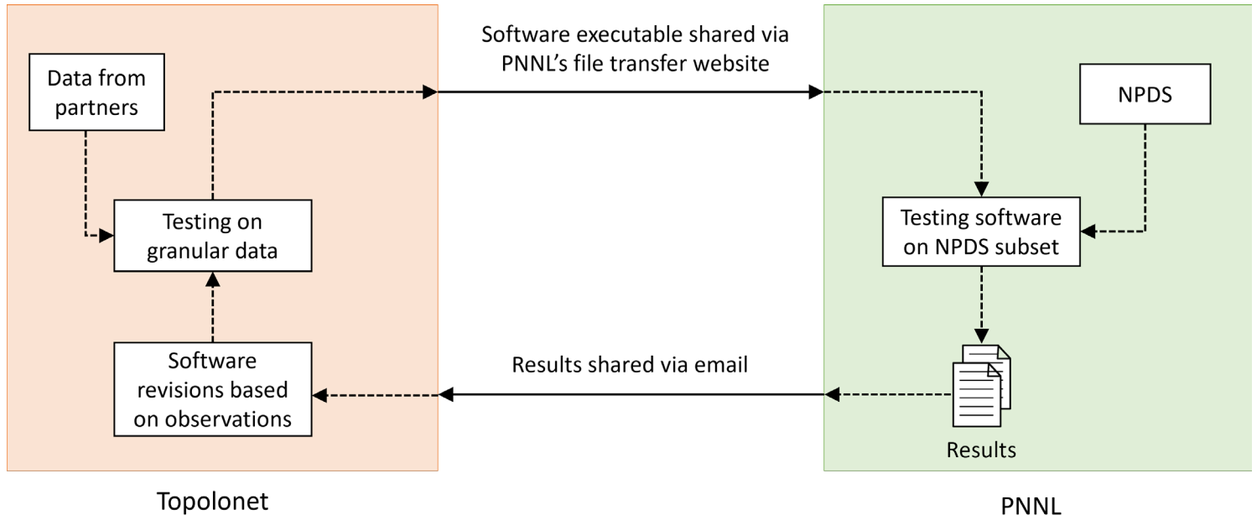
Background

- National PMU Dataset: repository of two years of PMU data from three US interconnections.
- No knowledge of topology, instrument configuration, data collection process, etc.
- NDAs ⇒ data may not be shared outside PNNL.
- How to maximize dataset utility within these constraints?

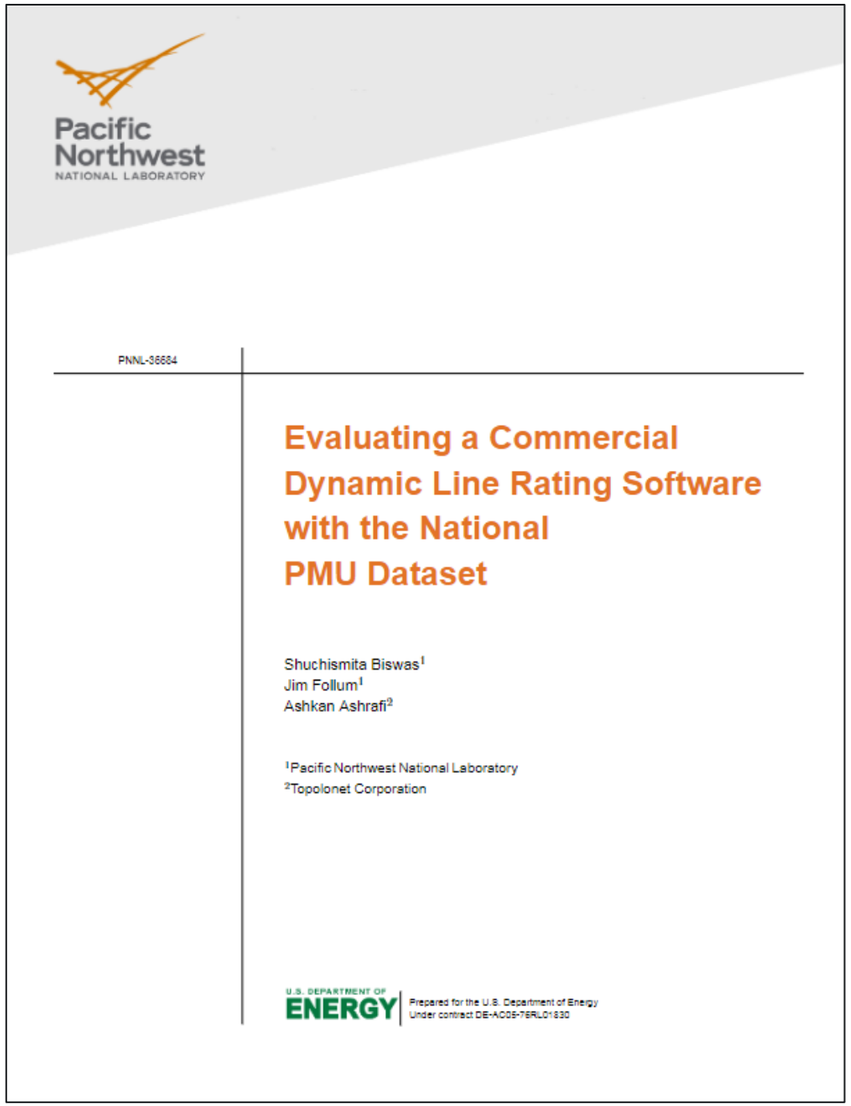
Blind Validation Methodology



- Cumbersome? Yes, but still provides value.
- Avoid duplication of effort in setting up data handling infrastructure.
- Risk mitigation by checking performance on unseen data.

Dynamic Line Rating

- DLR seeks to optimize transmission line usage by real-time adjustment of capacity based on environmental conditions and system performance
- Topolonet Corporation has a DLR solution called LineID that uses PMU data from both ends of a transmission line to estimate line parameters, loadability, and ampacity
- Does not need weather information



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Evaluating a Commercial Dynamic Line Rating Software with the National PMU Dataset

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U.S. DEPARTMENT OF ENERGY | Prepared for the U.S. Department of Energy Under contract DE-AC05-76RL01830

Study Set-up

- Stage 1: Feedback on usability, computation speed, noisiness in outputs provided after processing 1-hour data blocks
- Stage 2: Randomly selected 24-hour data blocks processed by LineID

- Two 345 kV transmission lines:
  Line-A (~25 miles) and Line-B (~100 miles)
- Three randomly chosen 24-hour data blocks from three seasons
- 3-phase measurements from both ends of the line, PMU reporting rate – 30 fps

- Computation time: ~20 mins (100-sec data window)
- Validation was qualitative:
  - ✓ Are parameter estimates consistent across seasons?
  - ✓ Can observed trends be explained by changes in power flow, weather conditions, time of day, etc.?
  - ✓ Are parameter estimates consistent in the presence of minor disturbances?

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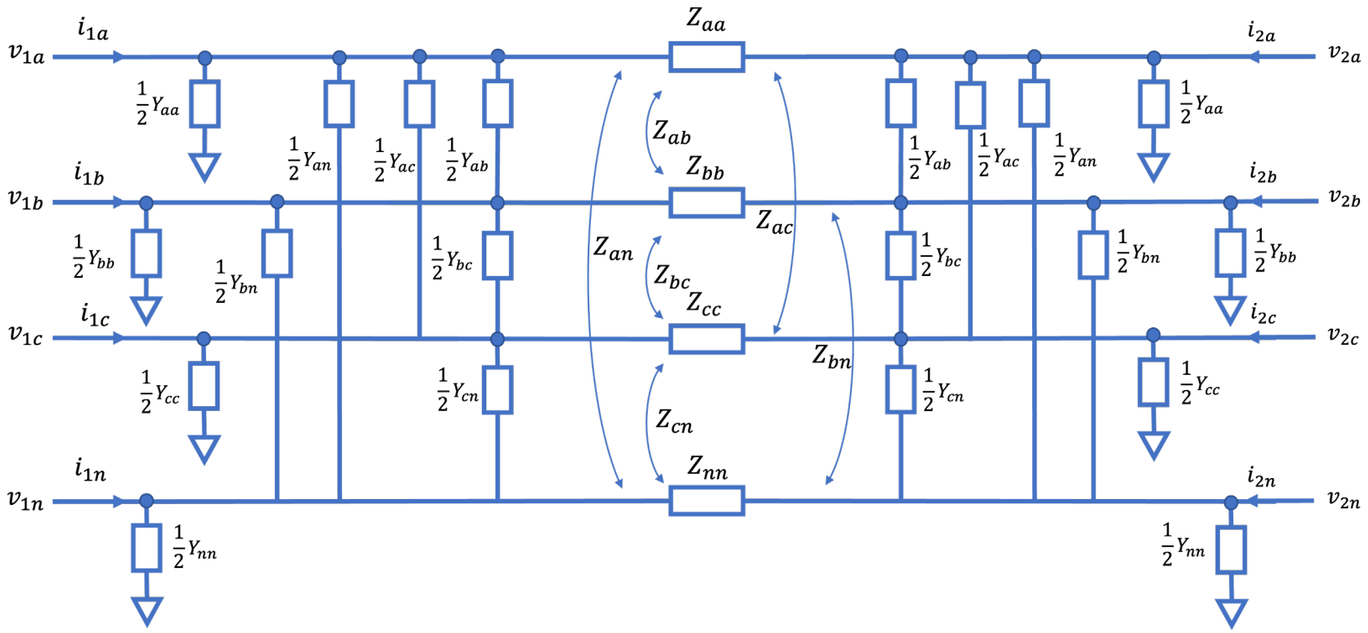
Transmission Line Model

- Z_{ii} are the series self-impedances of the line
- Z_{ij} are the impedances of earth return current path
- Y_{ii} are the shunt admittances of the line
- Y_{ij} are the mutual shunt admittances of the line



Pi-Model of Transmission Lines

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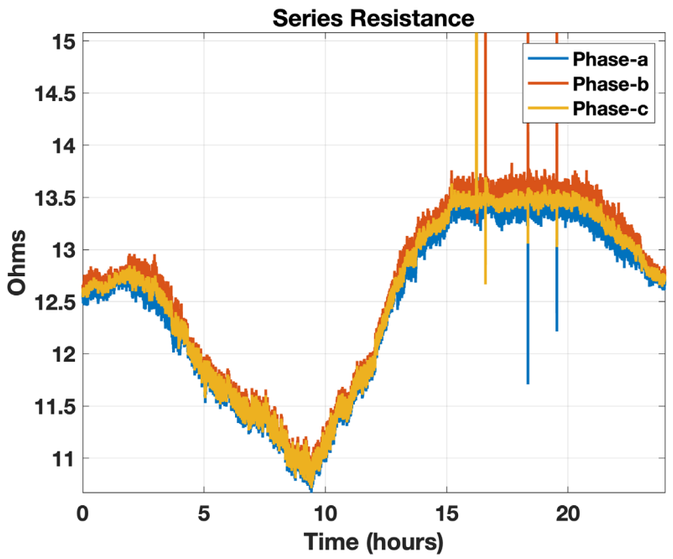
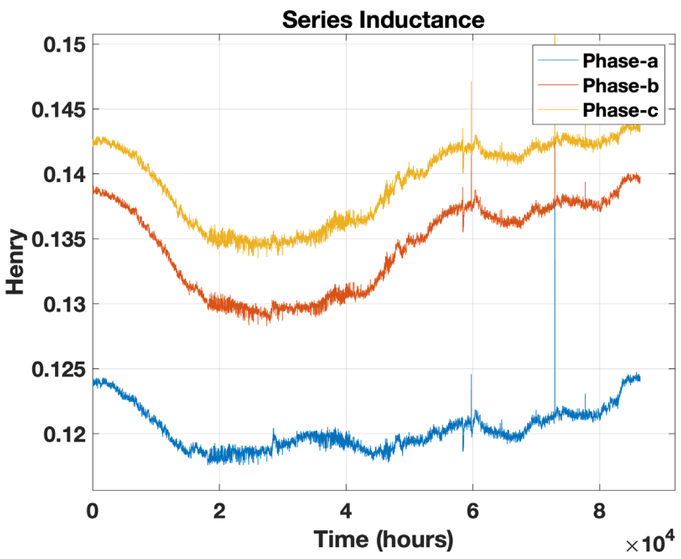
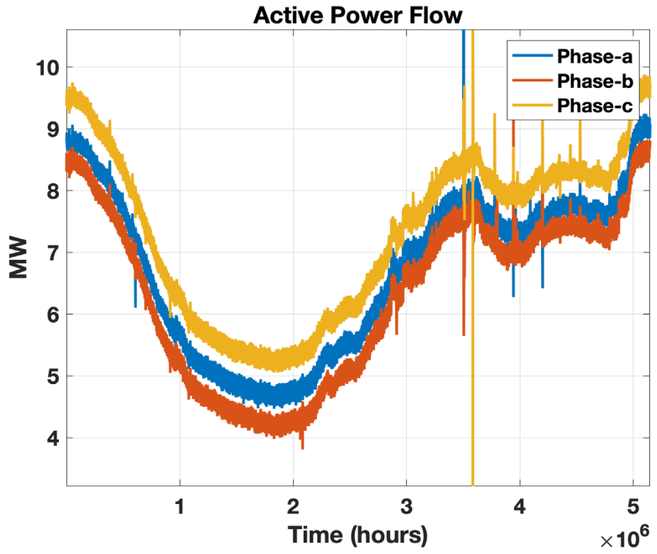
November

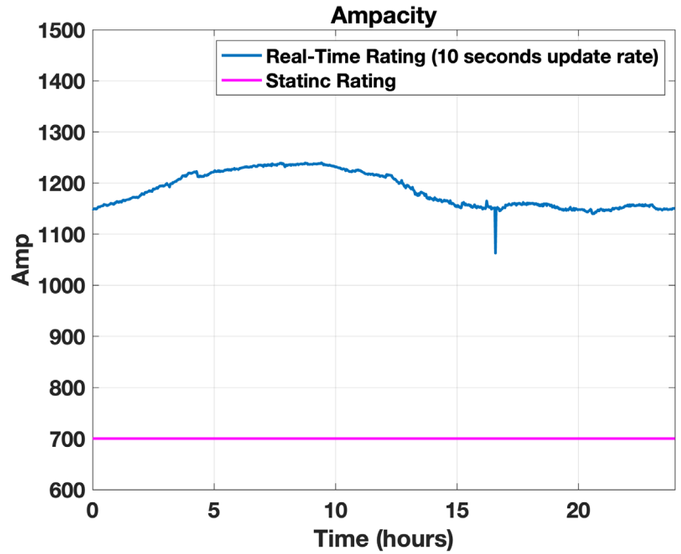
230KV – 140km Line in Colombia

- Shows changes of resistance and inductance by the time of the day
- Ampacity increases when the conductor is cooler









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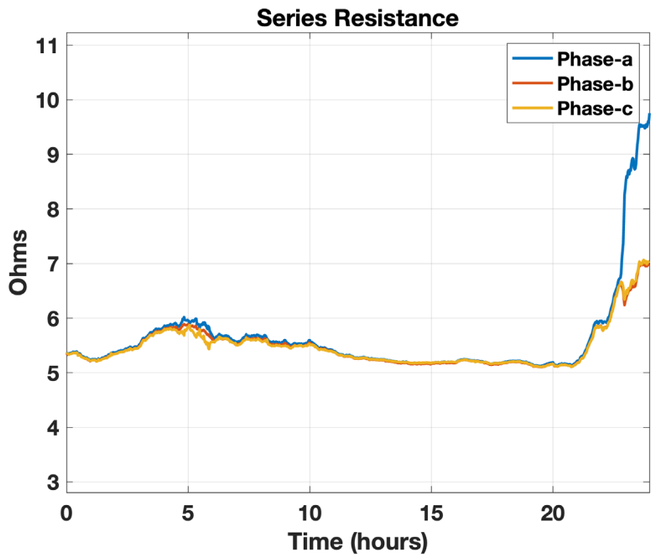
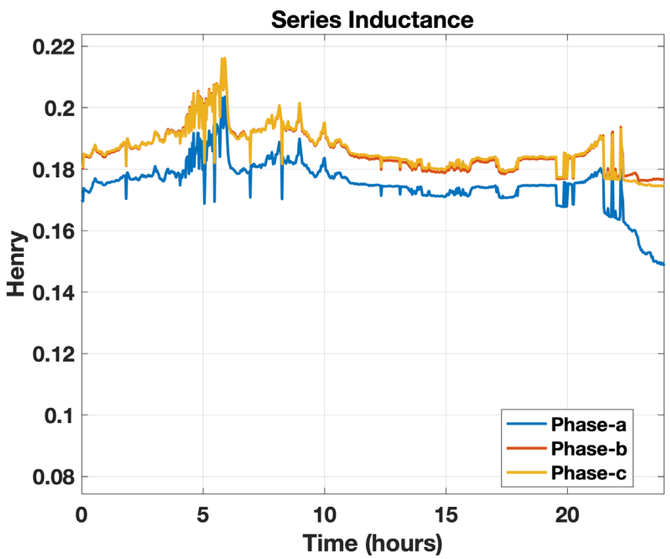
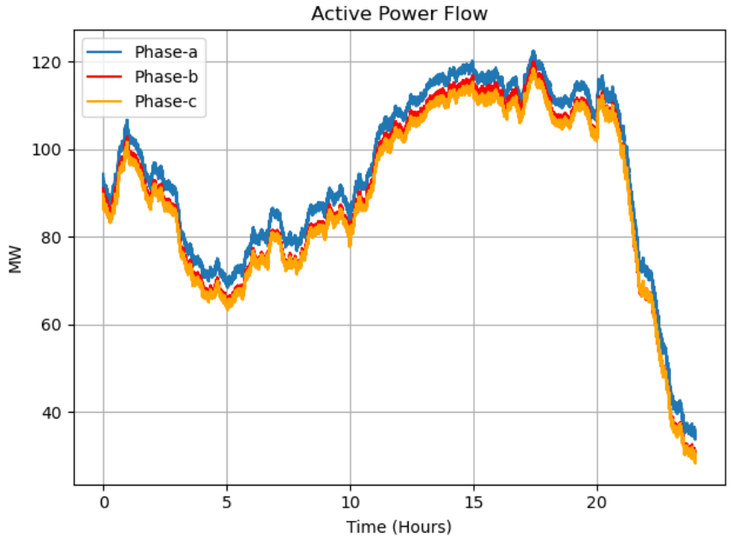
December

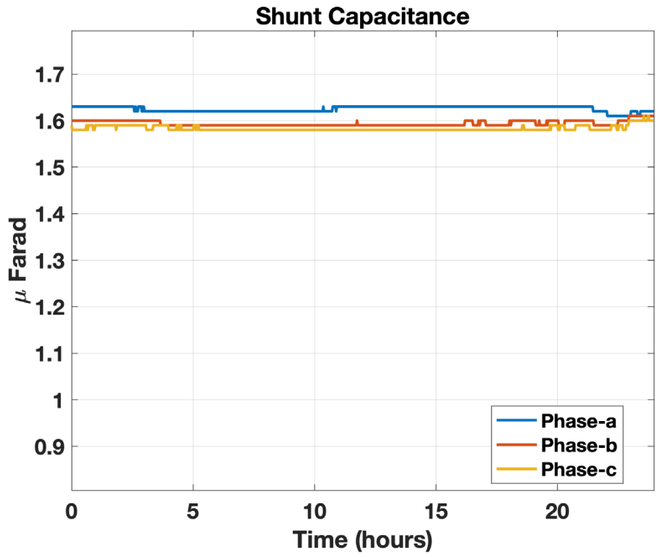
Line-B (100 miles)

- When the power flow is low, the error caused by bias in CT/PT increases in resistances and inductances
- The bias error in shunt capacitances does not depend on the power flow





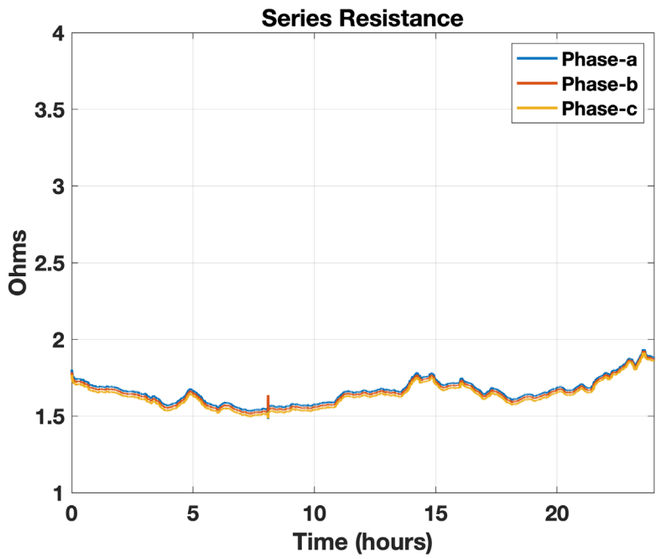




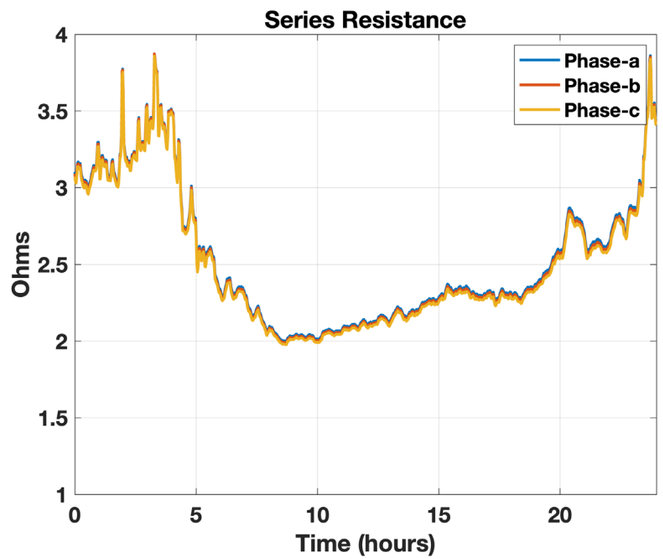
Line-A (25 miles)

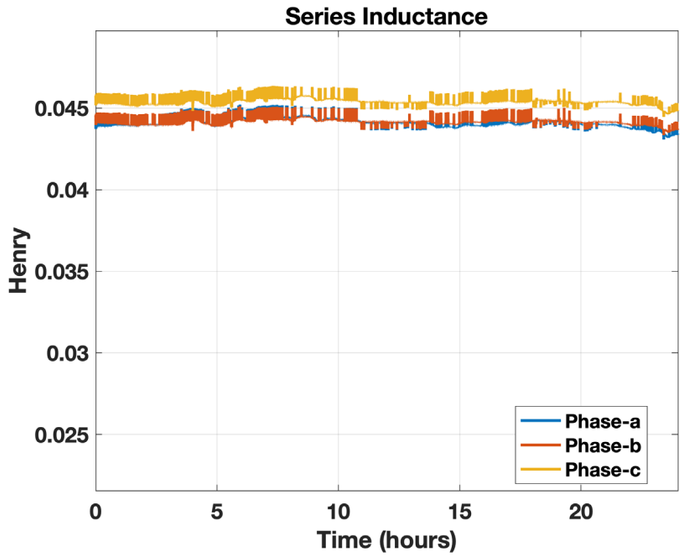
- In warmer seasons, the resistances are generally higher

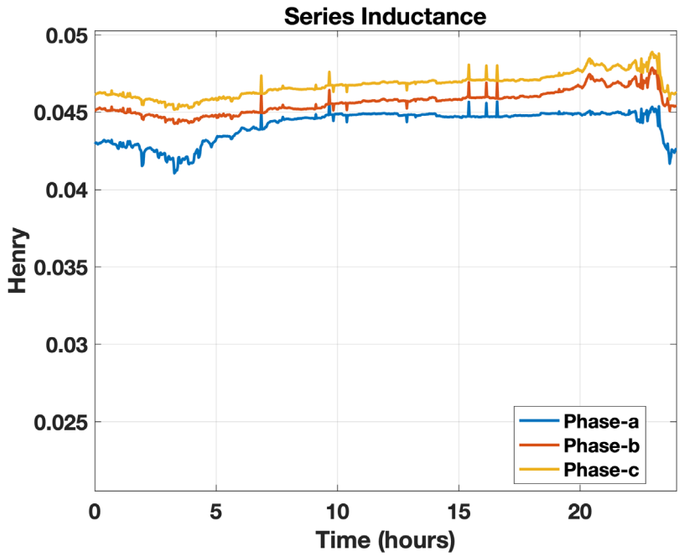
January



September







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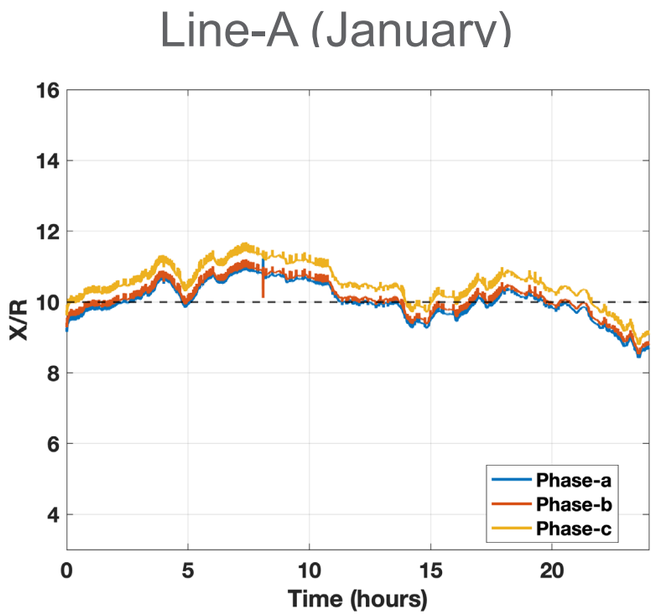
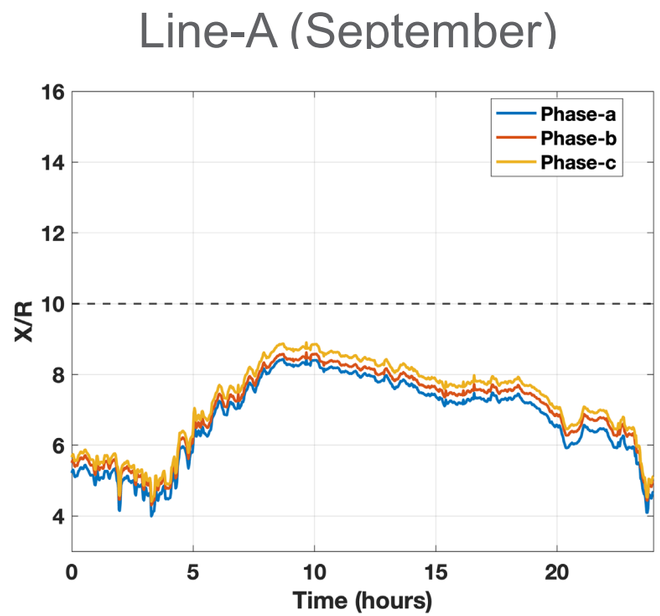
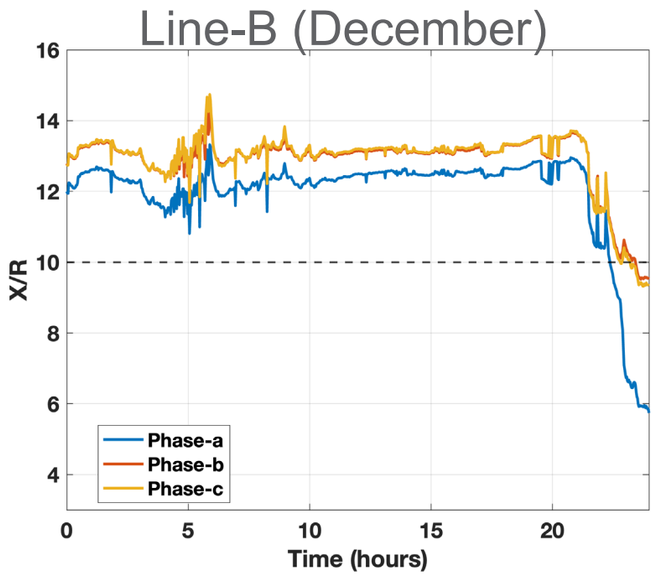
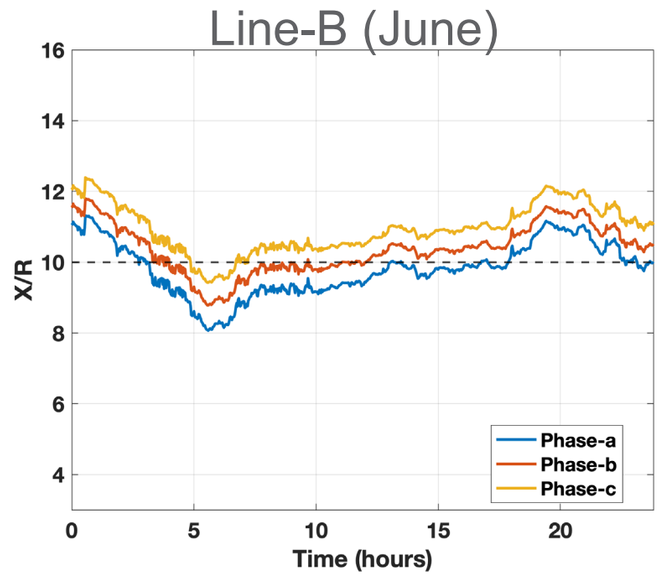
X/R Ratio

- Lossless assumption is valid if X/R ratio > 10.
- Results show that X/R ratio is not constant and can be lower than 10.
- Lossless assumption not always valid.



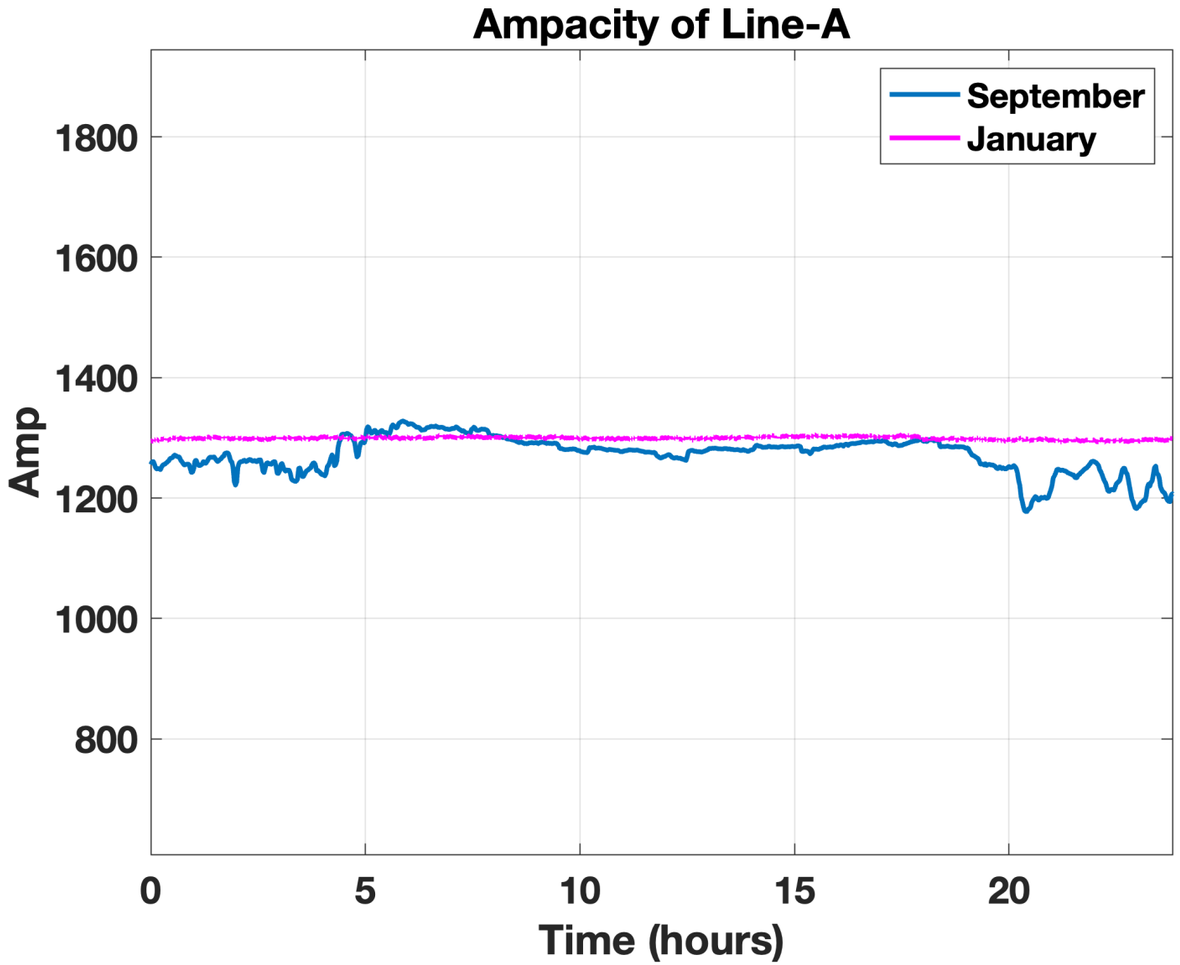






Ampacity

- Ampacity is calculated based on the Maximum Power Transfer which is capped at 3SIL
- Calculation of thermal rating was impossible due to lack of cable data



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Key Takeaways

- We show how the NPDS repository can continue to provide value to the community within existing constraints.
- The blind-validation exercise helped make algorithmic and usability enhancements to the LineID software.
- Line parameters estimated by LineID qualitatively ‘make sense’.
- Consistent estimates obtained in the presence of disturbances like voltage oscillations.
- Impedance estimates are more reliable when line power flows are high.

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Thank you