Enhanced Distribution Feeder Fault Location

Lihan He, Zhilin Wu, Zhihan Xu, Ilia Voloh, Terrence Smith

GE Digital Energy

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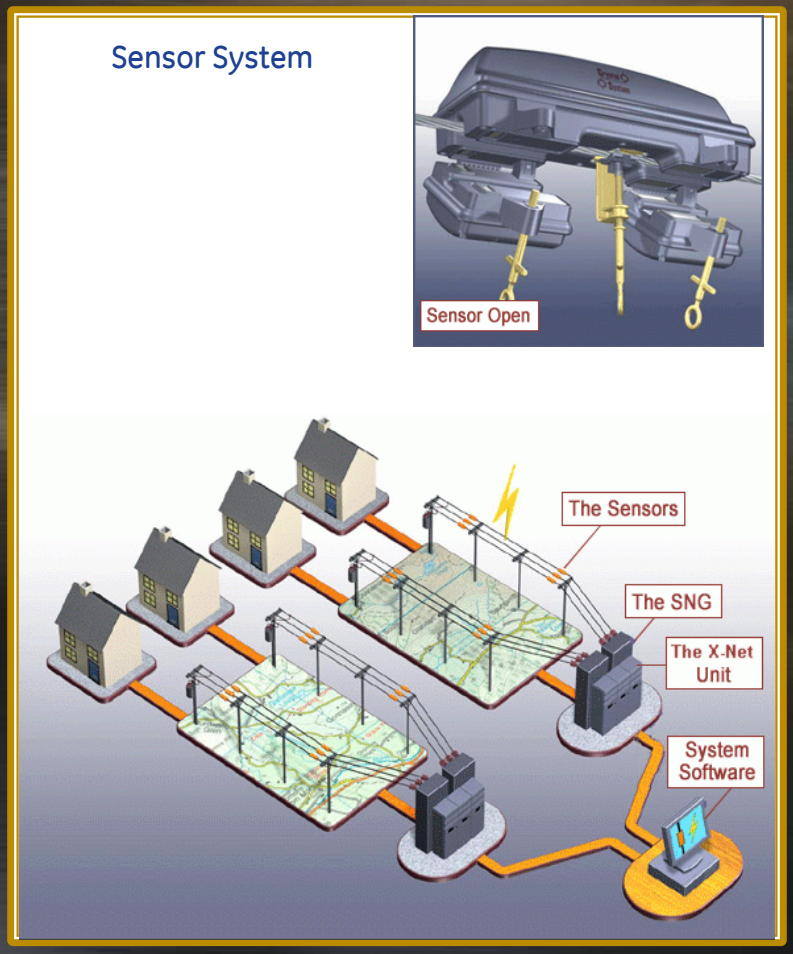
Overview

- Background
  - Fault location in a distribution network. The distribution network usually has a large number of laterals and limited fault recorders and sensors.
  - Current/voltage sensors are available in the distribution network to help fault location
- Targets
  - Develop a fault location method using current/voltage sensors in the network
  - Evaluate effects of uncertainties on the proposed fault location method

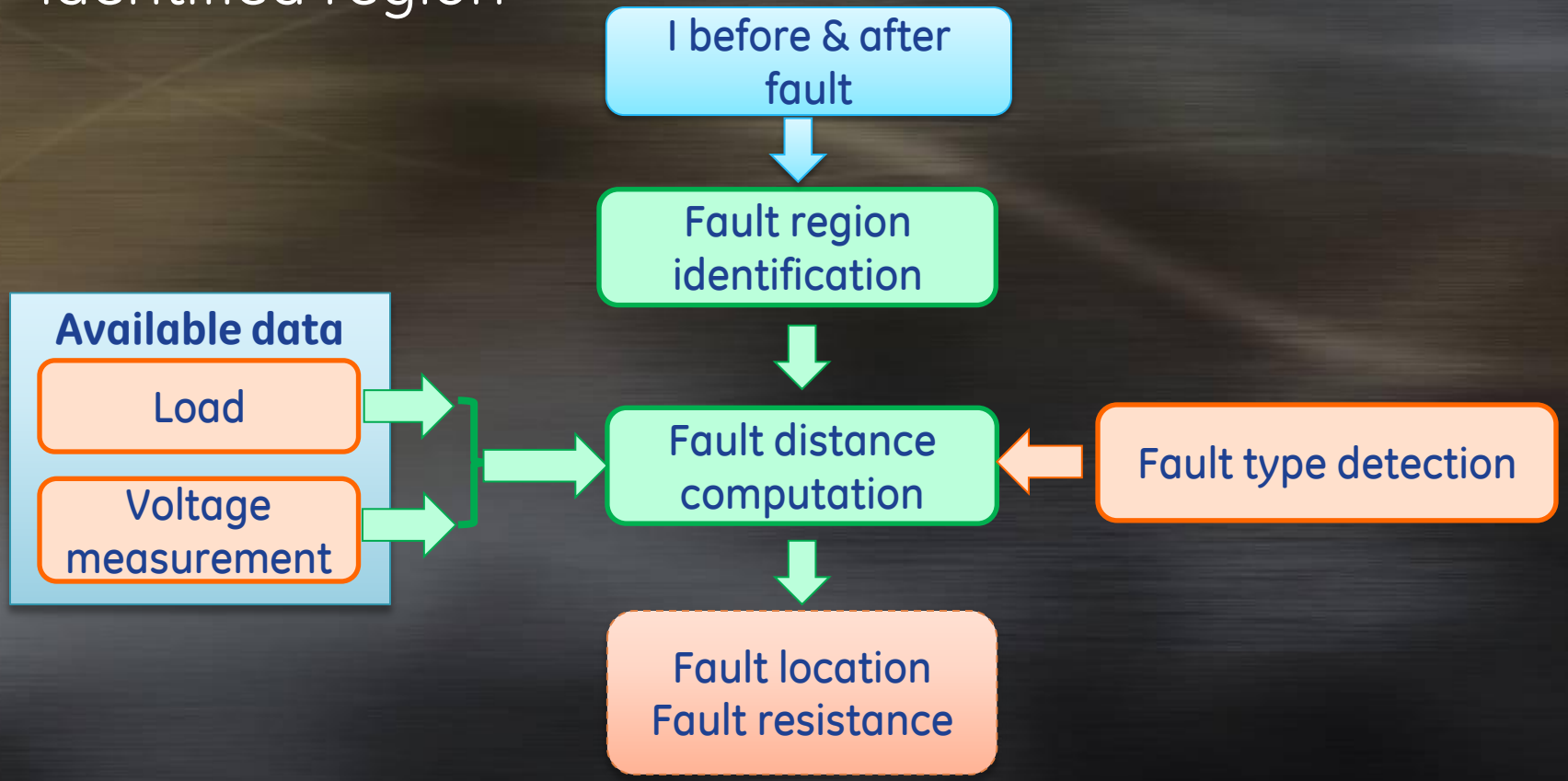
Known Distribution System

- Radial distribution network, with known topology and line parameters
- Fault recorder at substation
- Known sensor position and measurements
- Known load position



Algorithm Flowchart

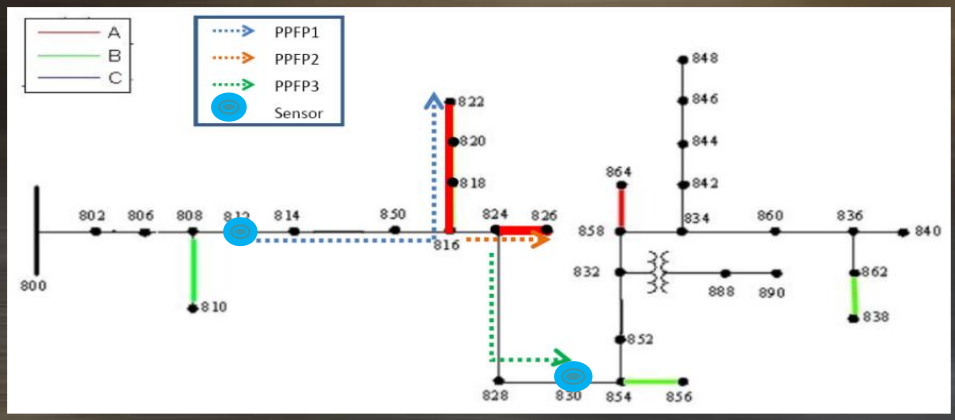
- The complex feeder network is partitioned by the sensors into a few smaller regions
- Fault location calculation is performed in the identified region

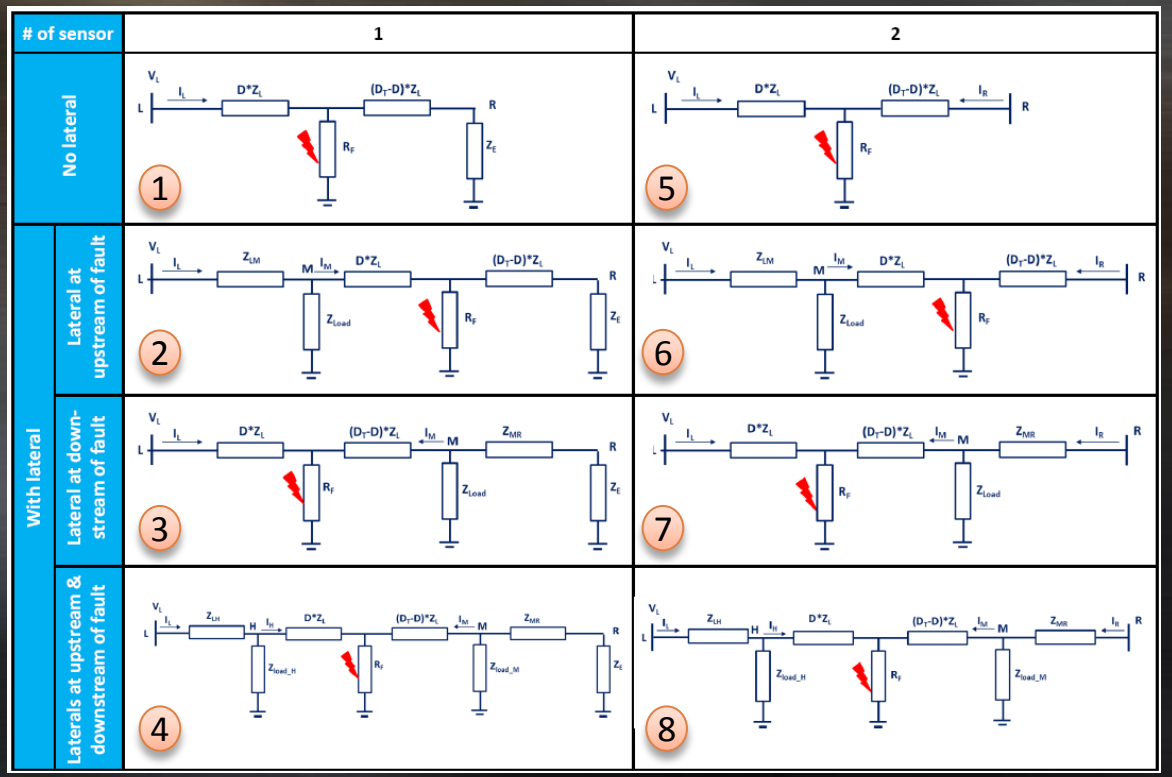


Fault Location Algorithm - 8 Scenarios

Procedures

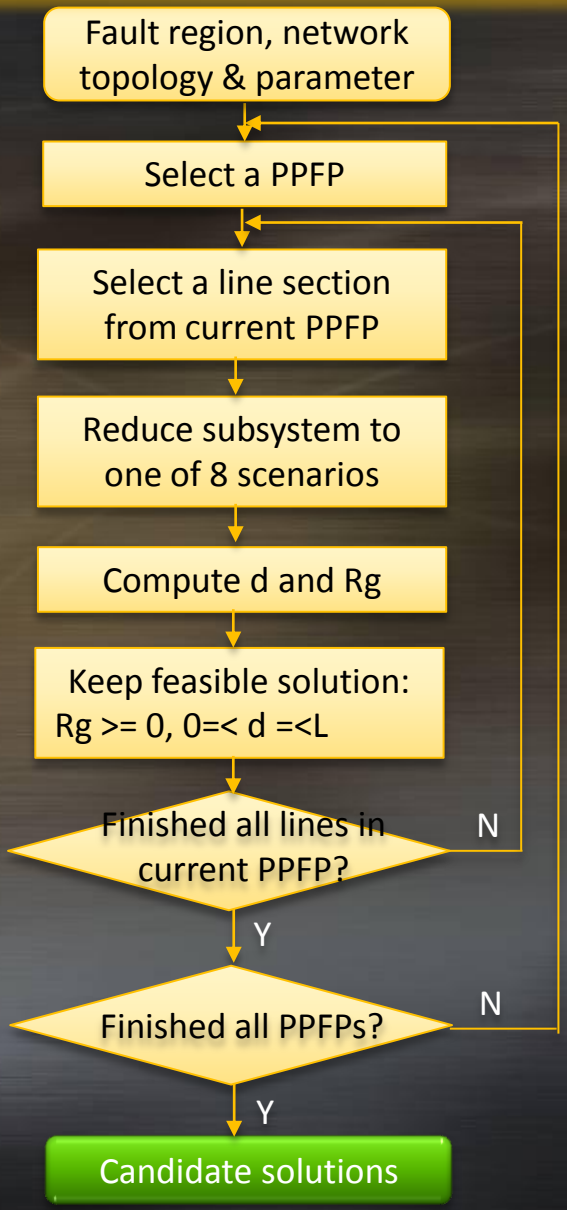
- Possible power flow path (PPFP)
- Reduce the sub-system to one of the eight scenarios
- Calculate fault distance
- Evaluate individual PPFP results (Rg, d)

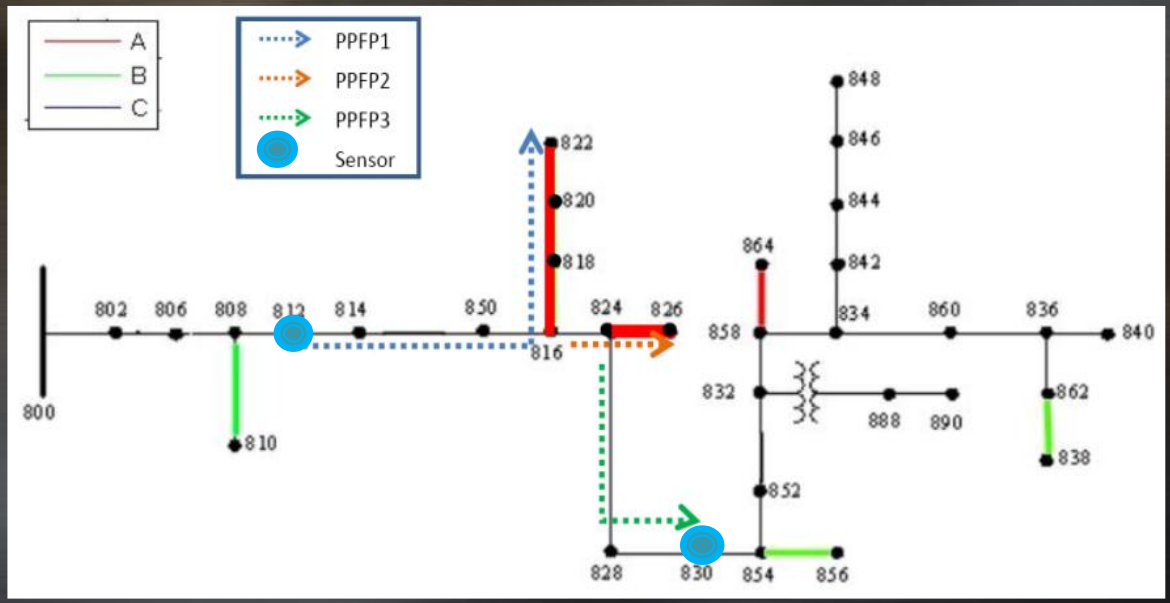




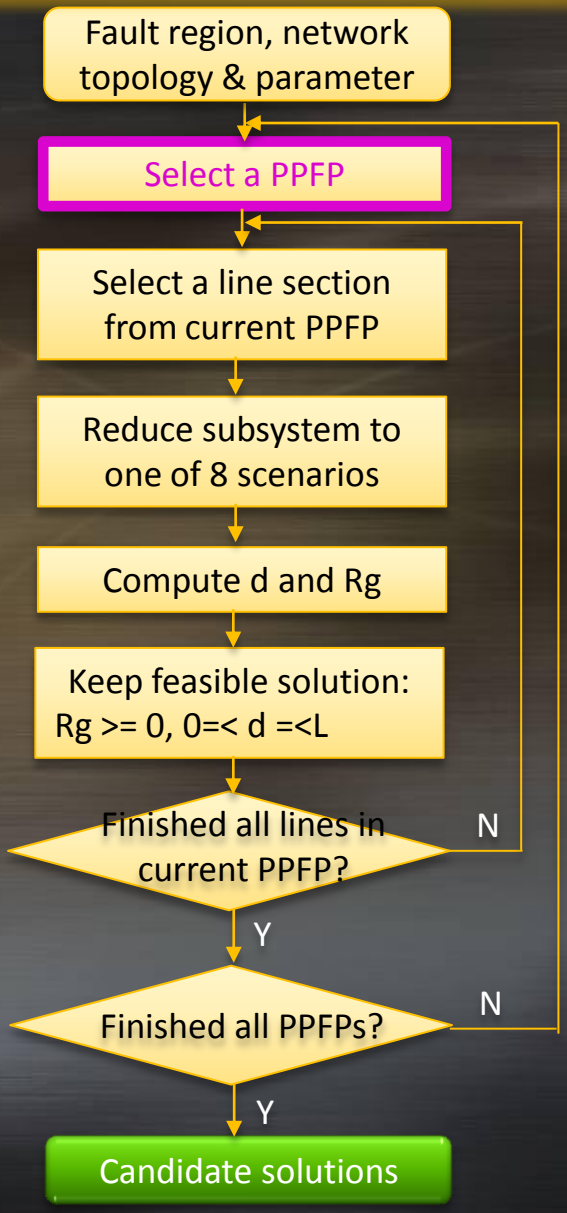
Fault Location Procedures

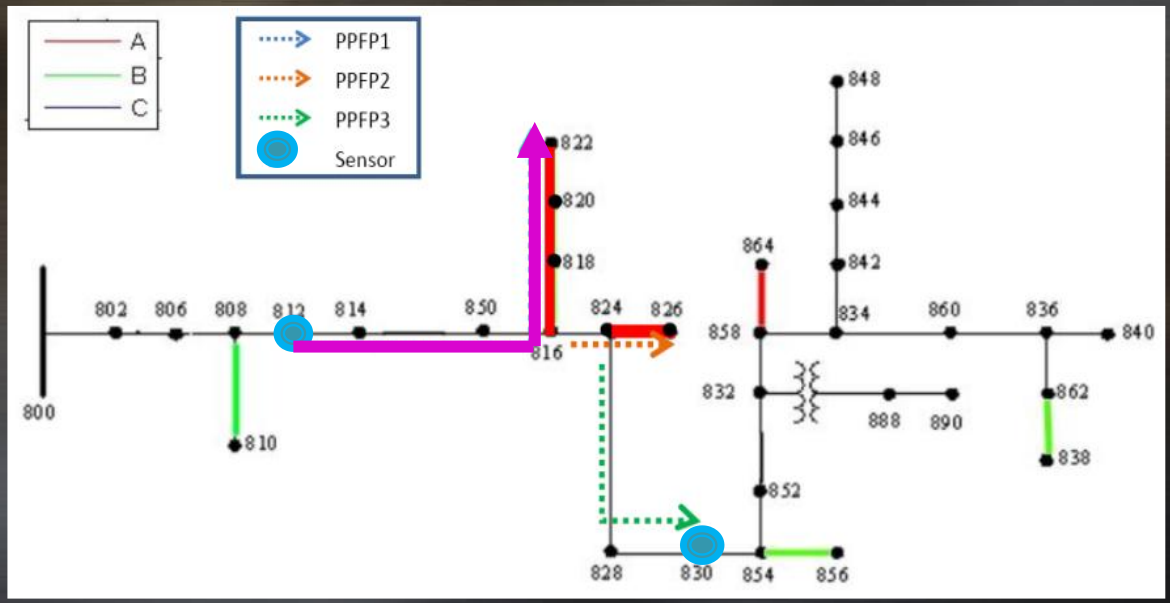
Key Function





Fault Location Procedures





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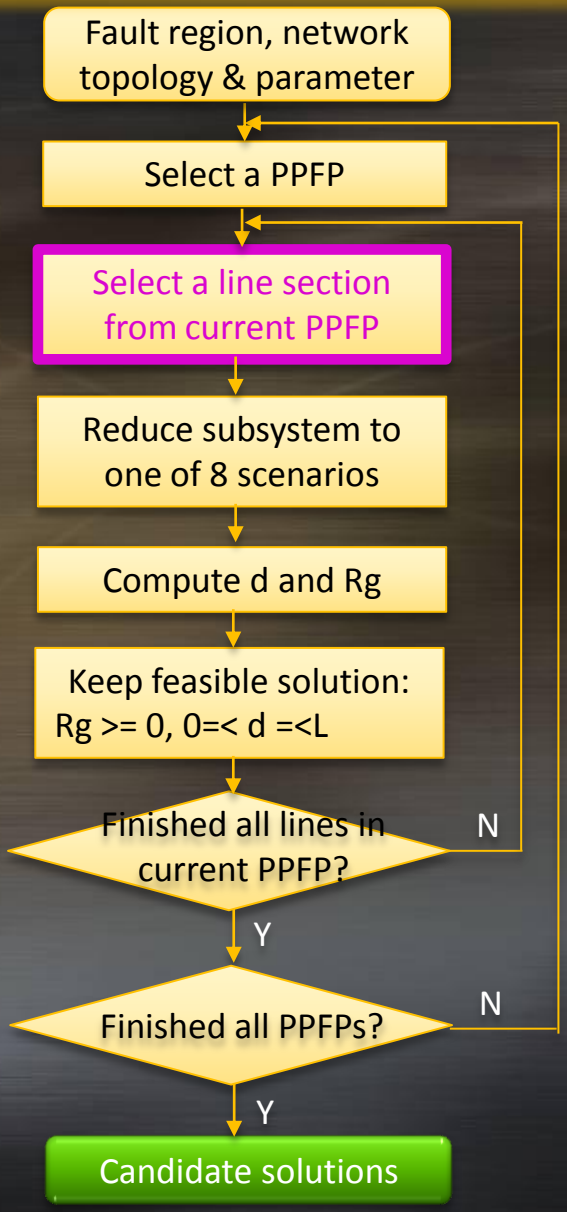

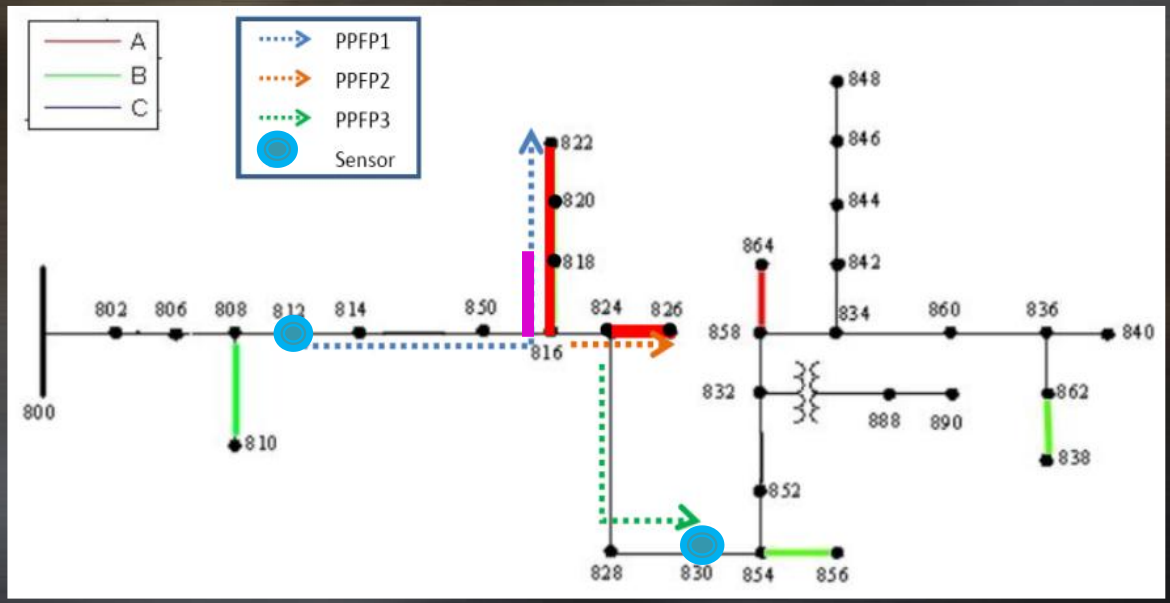

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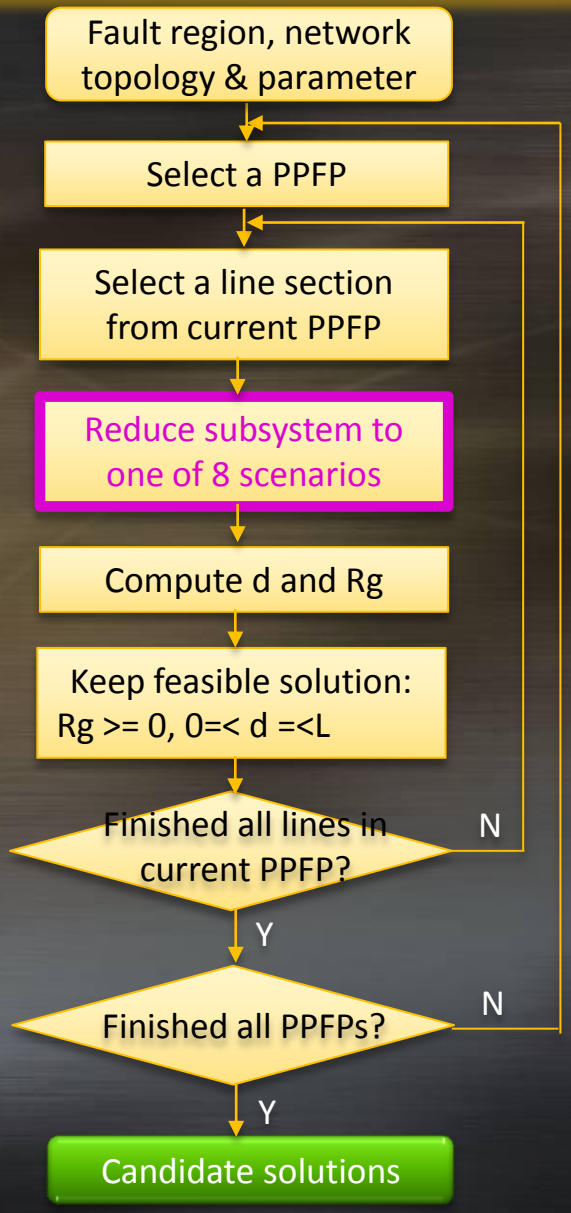
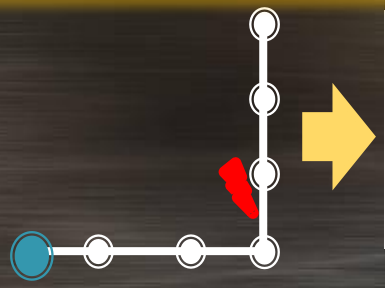
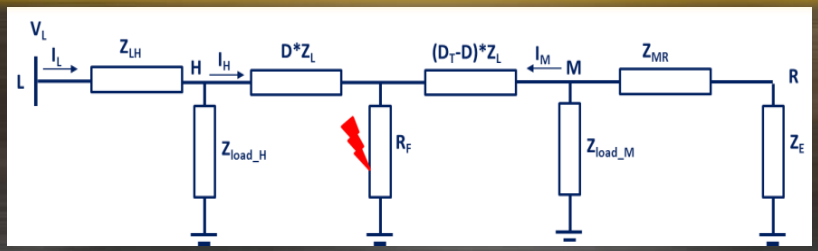
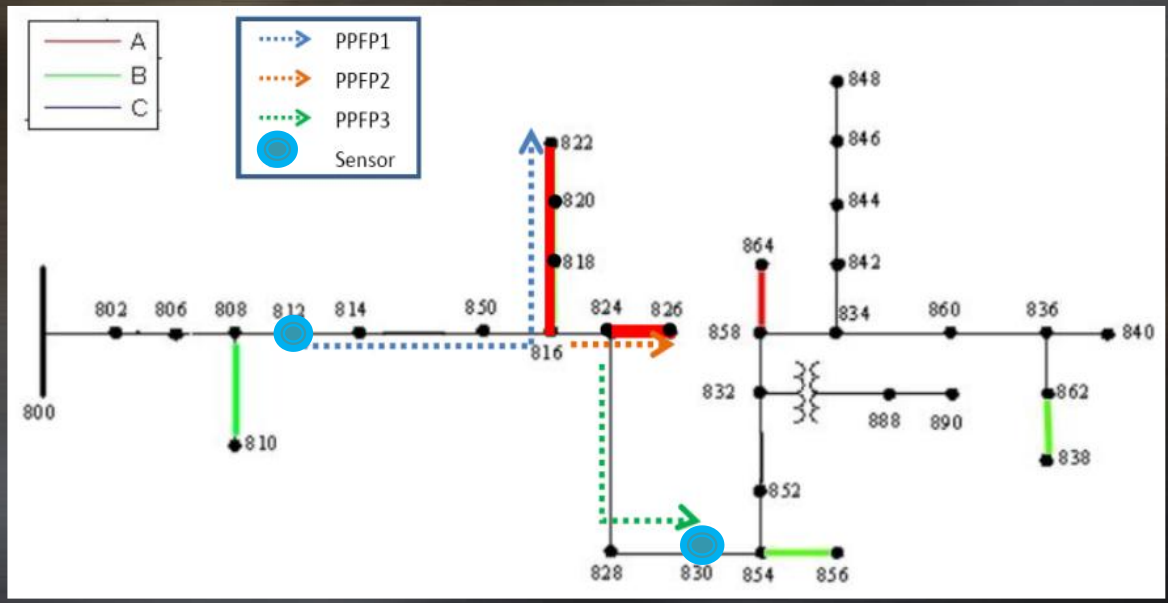
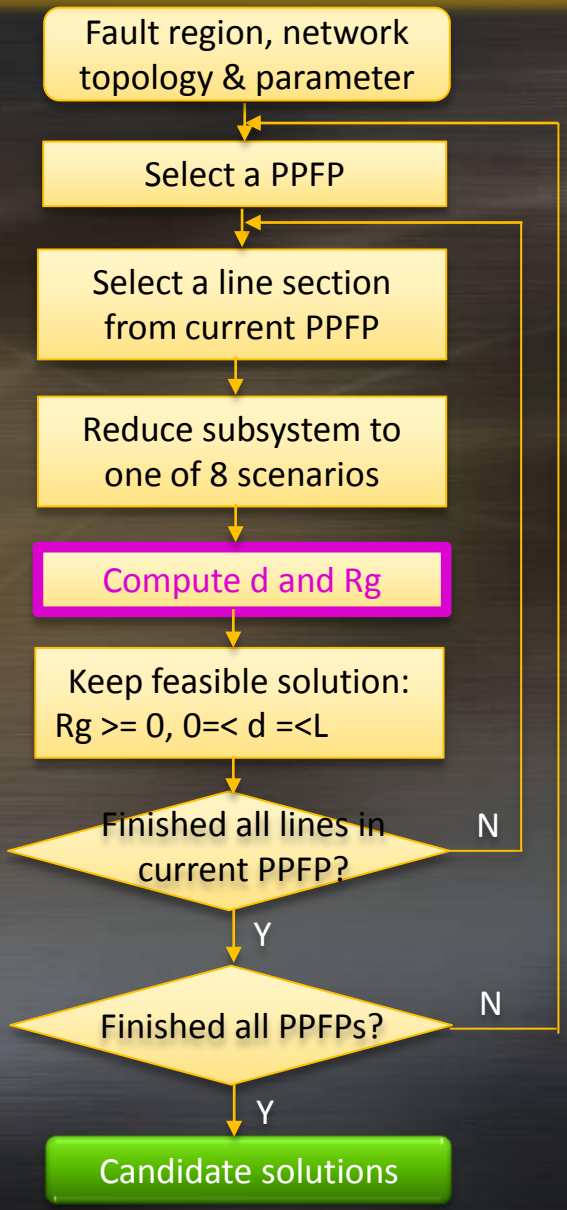








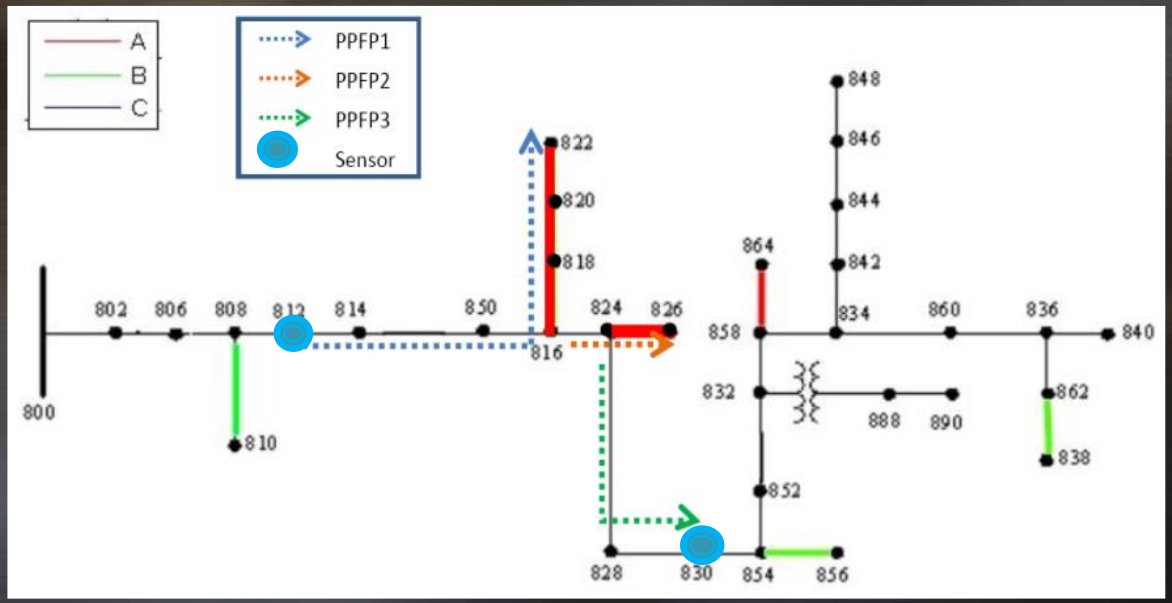
Fault Location Procedures



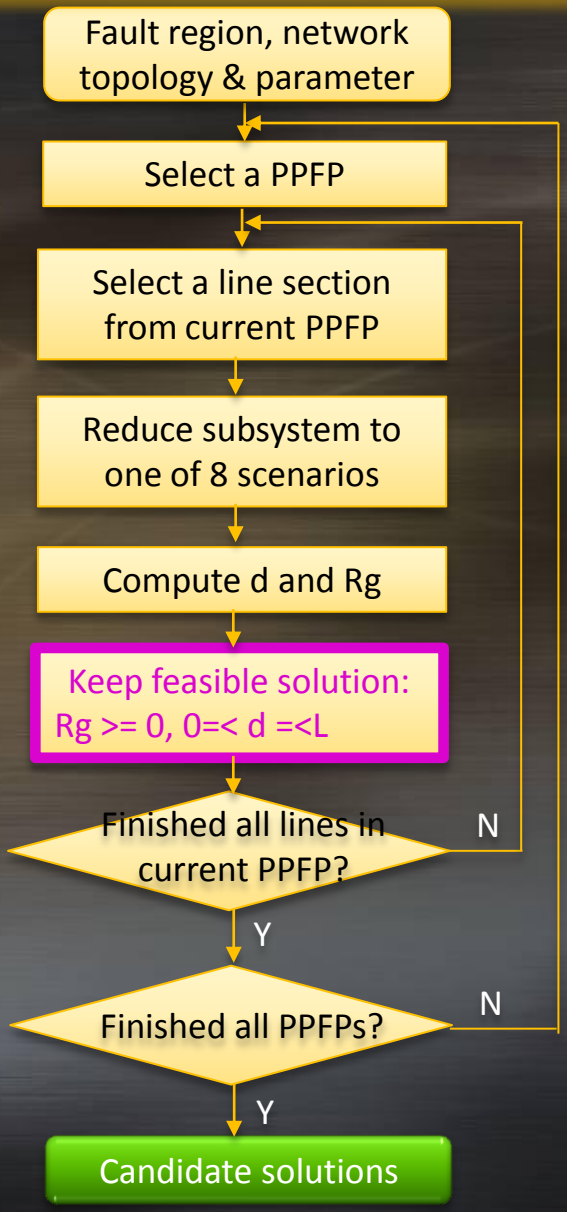
$$d = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$Rg = \frac{(V_L - DZ_L I_L)[(D_T - D)Z_L + Z_E]}{I_L(D_T Z_L + Z_E) - V_L}$$

$$\begin{aligned}
V_M &= V_L - Z_{LM} I_L \\
I_M &= I_L - \frac{V_L - Z_{LM} I_L}{Z_{Load}} \\
a &= Im\left[Z_L^2 \left(D_T Z_L + Z_E - \frac{V_M}{I_M}\right)^*\right] \\
b &= Im\left[-Z_L \left(D_T Z_L + Z_E + \frac{V_M}{I_M}\right)\left(D_T Z_L + Z_E - \frac{V_M}{I_M}\right)^*\right] \\
c &= Im\left[\frac{V_M}{I_M}(D_T Z_L + Z_E)\left(D_T Z_L + Z_E - \frac{V_M}{I_M}\right)^*\right]
\end{aligned}$$

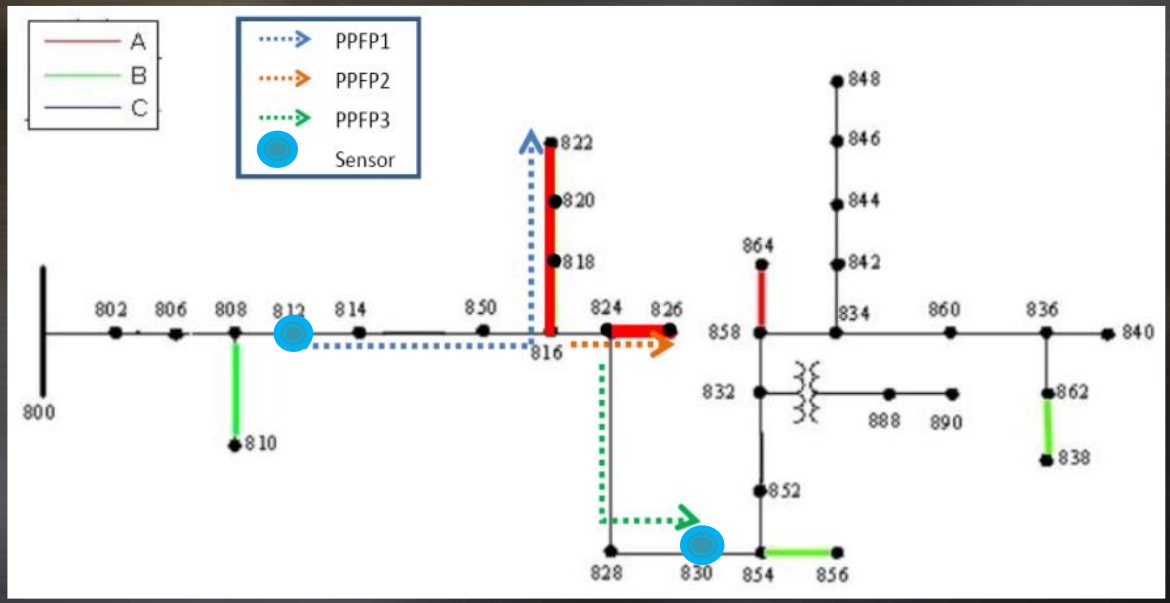


Fault Location Procedures



$Rg >= 0$?

$0 =< d =< L_{816\text{-}818}$?



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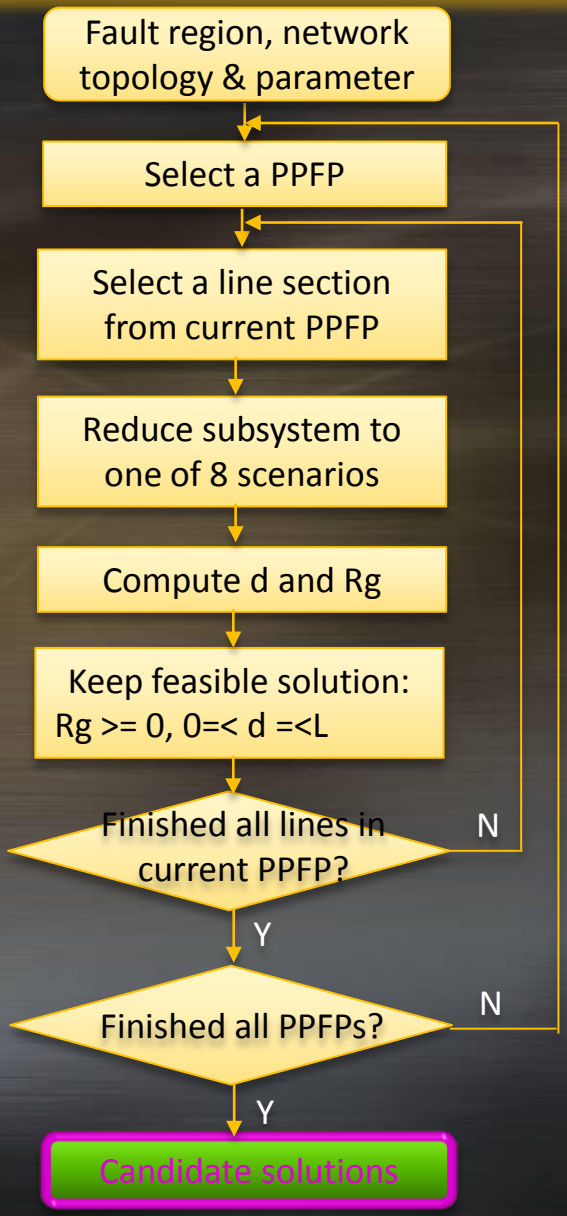
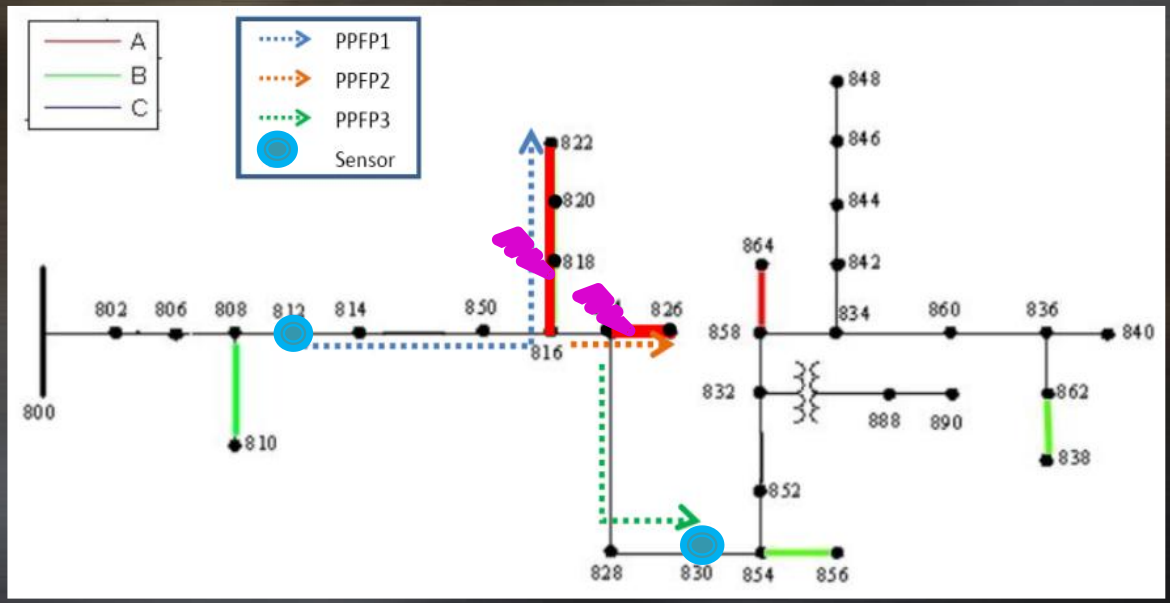
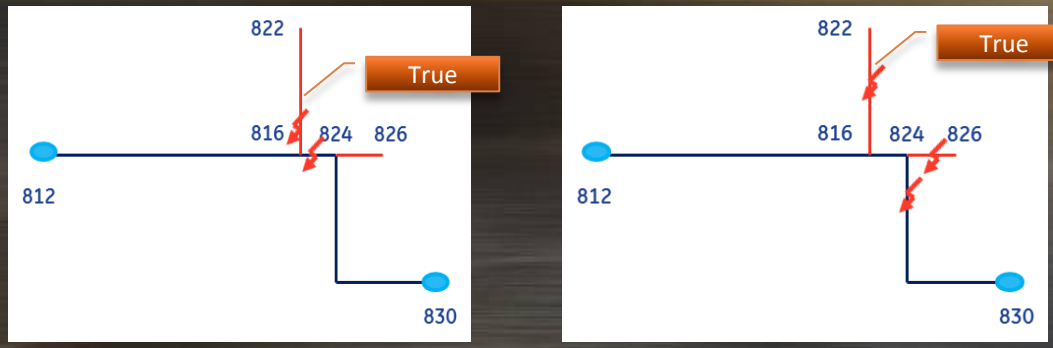


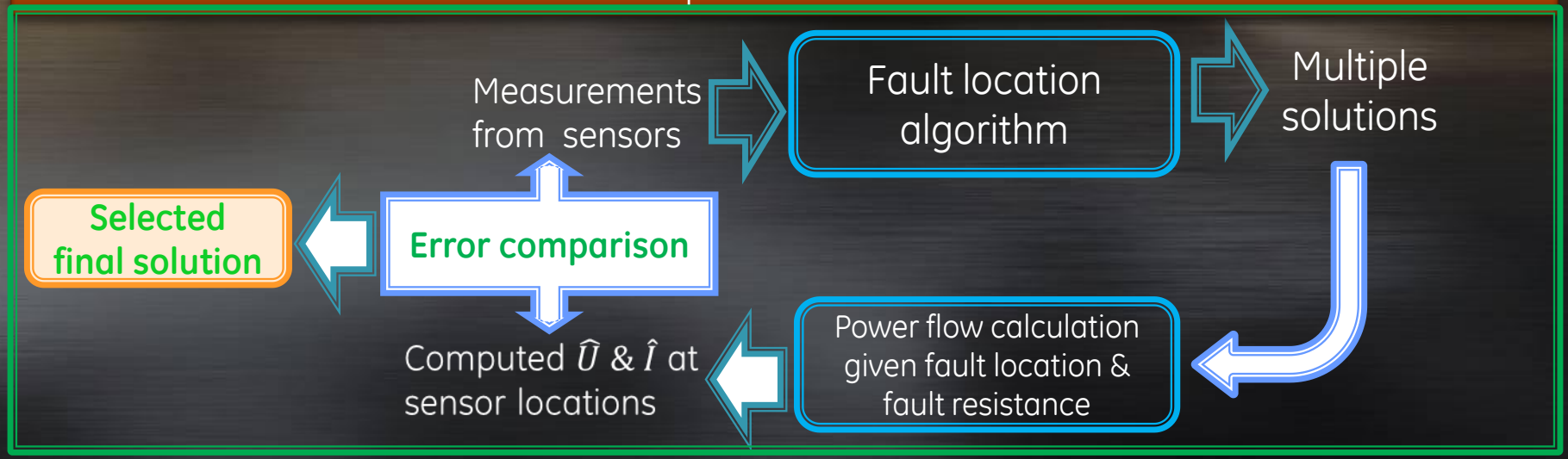


Elimination of Multiple Estimations



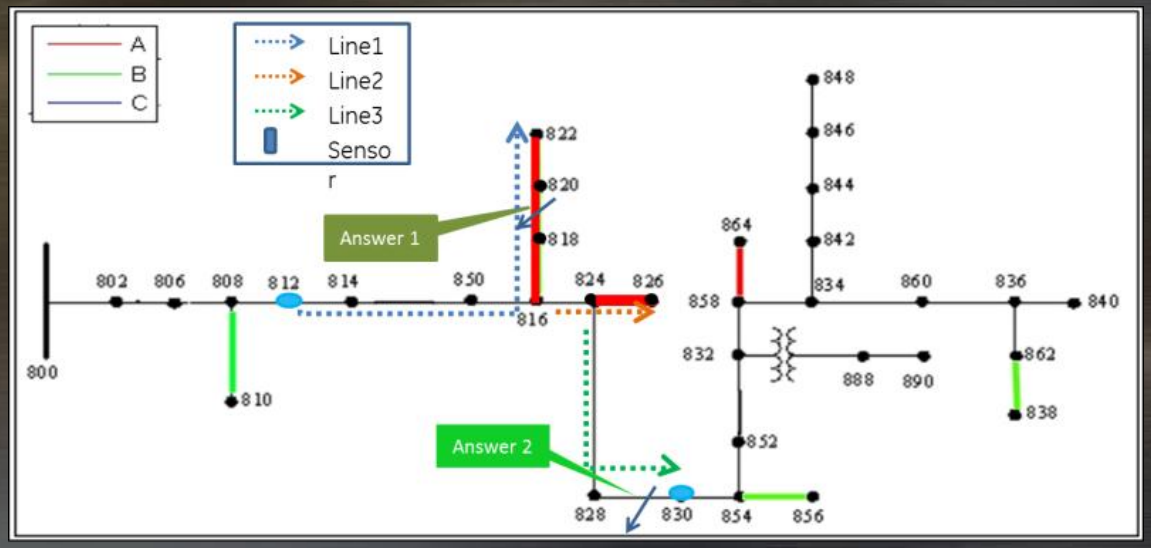
- With a possible location and R_g, there is a corresponding set of V/I at the sensors locations
- The true fault location may best fit the sensors measurement

Flowchart of Multiple Fault Location Identification



Example

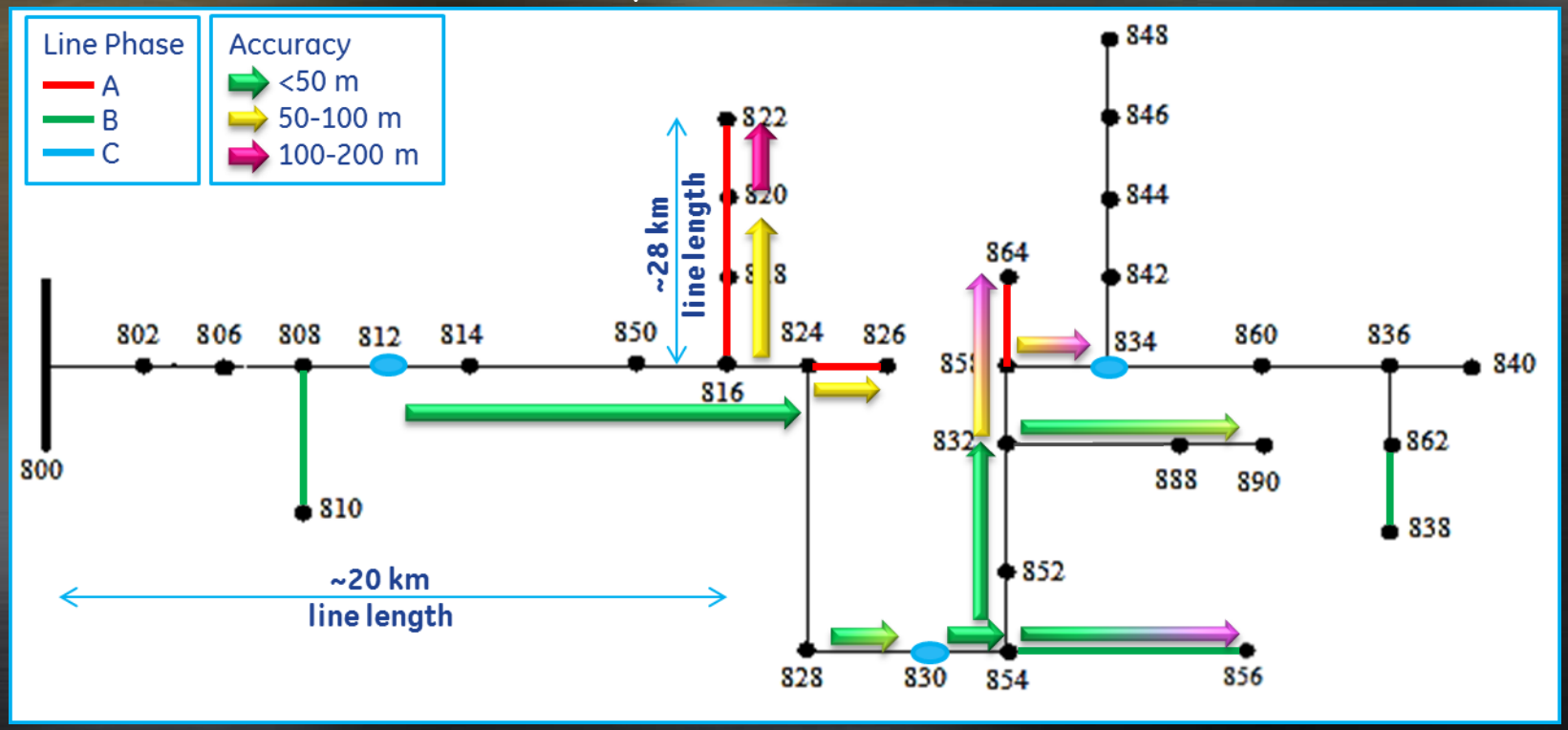
- Error for Solution 2 is much smaller than that of Solution 1, indicating that the fault is located at Solution 2



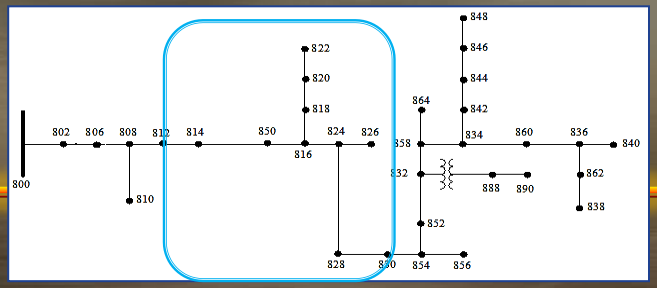
	Error	Decision
Solution 1	1.725	x
Solution 2	0.008	✓

Fault Location Results

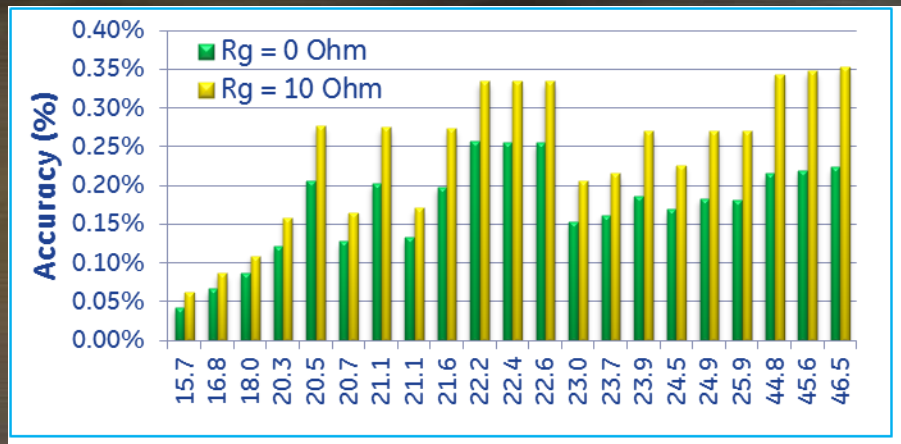
- Fault location accuracy is marked with “colored arrows”, at correspondence fault position
- Simulations are performed across the network with different levels of fault resistance
- For fault resistance of 10 Ω, location accuracy is mostly within 100 meters, except at some far end (>30 km)

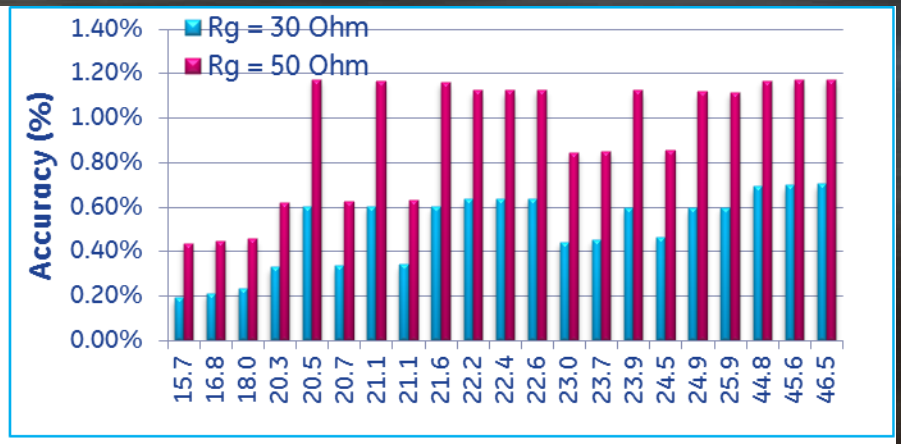


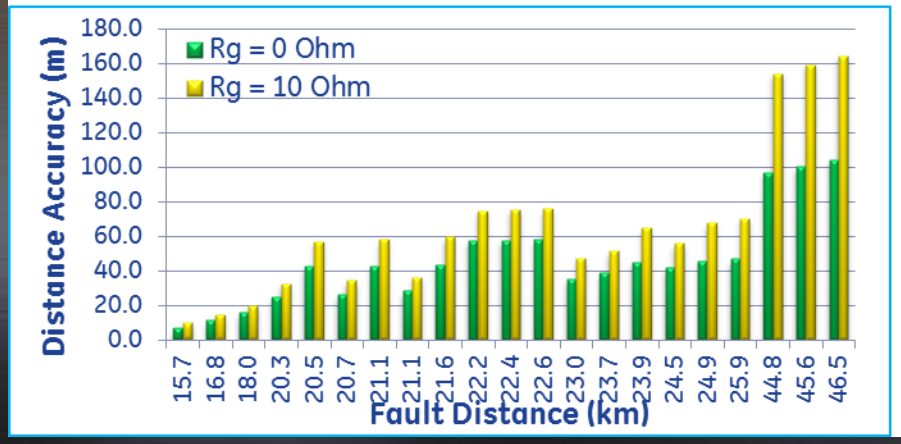
Simulation Results

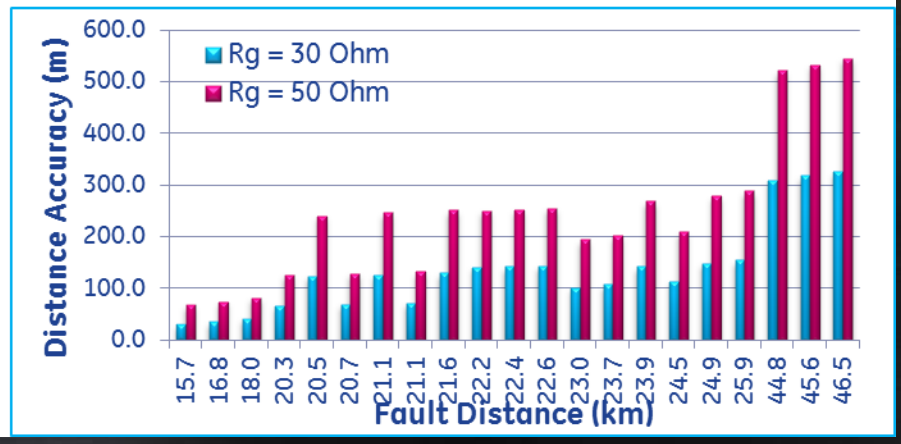


- 84 cases: 21 fault locations, 4 fault resistance (0/10/30/50 Ω)
- High fault location accuracy is achieved
- Better accuracy in lower fault resistance



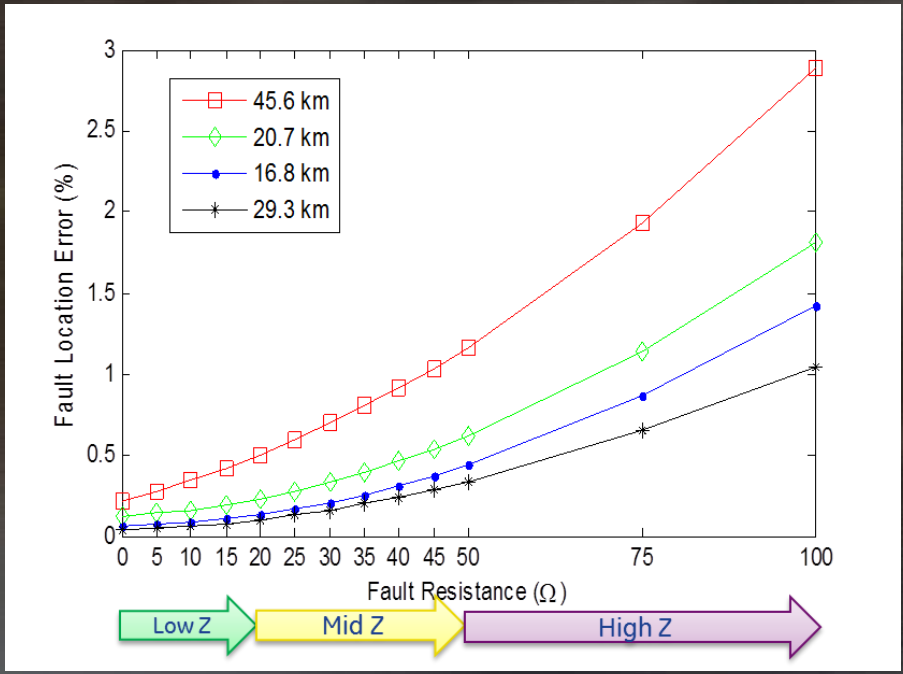






Robust to Fault Resistance

Goal: In reality, fault resistance is unknown and it may be in a large range. The robustness of the developed fault location system is studied under different fault resistance



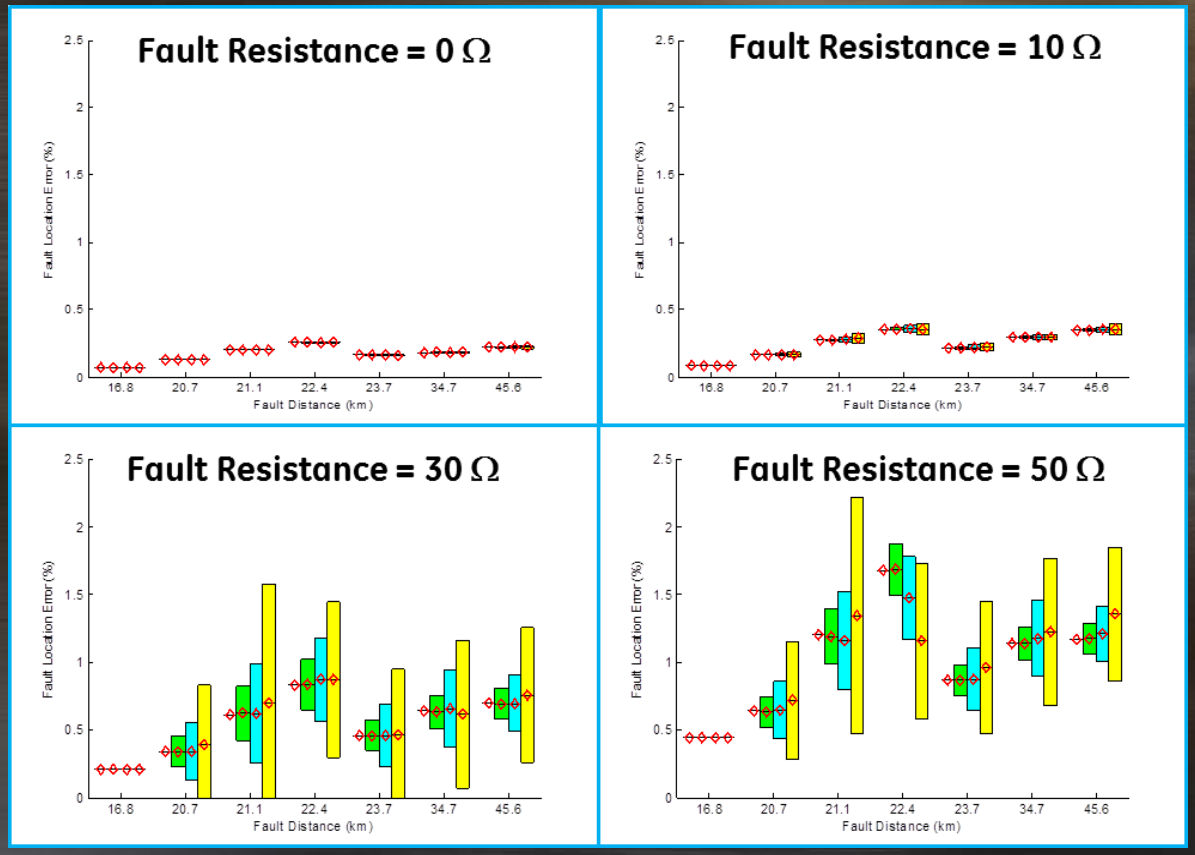
- Different fault positions are examined
- Fault location performance is mostly preserved in a wide range of fault resistance
- Even with higher fault resistance, the performance is acceptable

Load Uncertainty Impact

Purpose: This study tries to see the impact of load uncertainties on fault location

Evaluation: 11,200 simulations

- 7 groups of bars: corresponding to 7 fault positions
- 4 bars in each group: load uncertainty level of 0%, 5%, 10%, 20%
- Height of each bar: mean ± STD



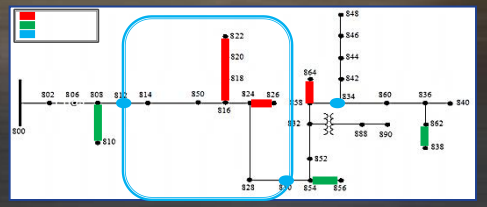
Conclusion

If loads values can be obtained within ±20% range of the true values, the fault location results should take about 1% uncertainty (or add 1% result error) in low fault resistance condition

Improvement with Capacitance

Purpose

- In the previous algorithm, line capacitance is ignored
- This study takes line capacitance into account

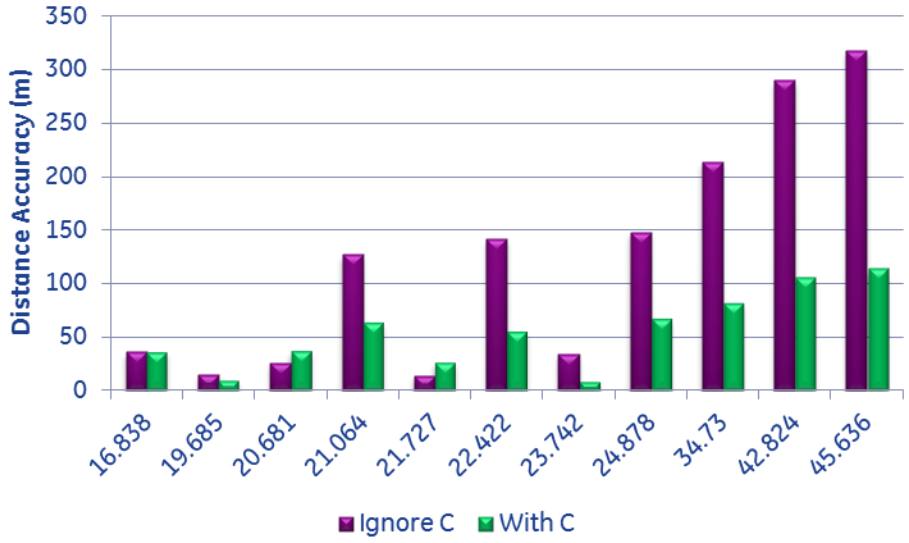


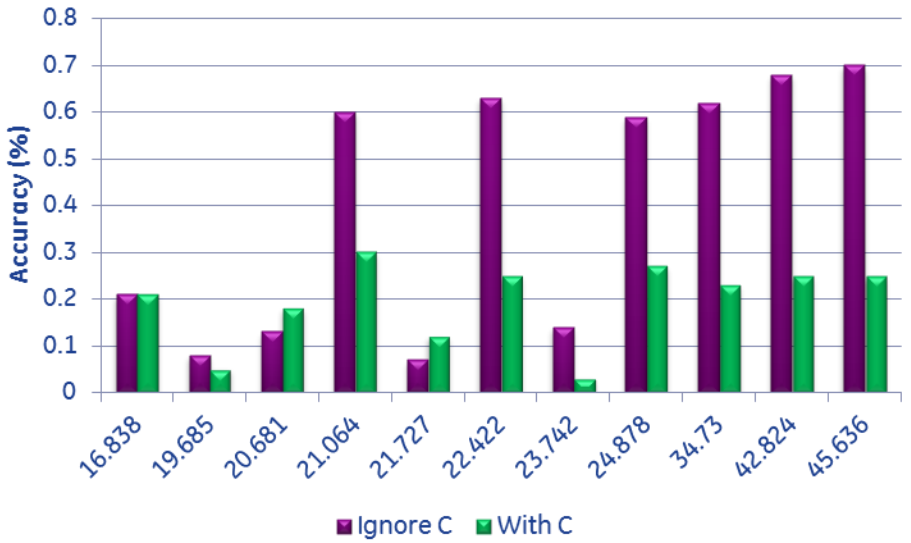
Simulation conditions

- Faults between 812-830
- 12 simulation cases are performed with Rg = 30 Ω

Discussions

- Significant improvement when capacitance is considered
- It's possible to use this approach in cable network





Conclusions

Robust and high performance feeder fault location is realized

- Multiple estimation problem is solved with a novel algorithm
- Both balanced/unbalanced network
- Network with different line configurations
- Lab experiment conducted to further evaluate the method

Key factors evaluated

- Load
  - Use historical data: ±20% load uncertainty has little impact on the developed algorithms
  - An algorithm is developed to improve load estimation
- Voltage measurement
  - If available: used in algorithm
  - If unavailable: a novel algorithm to estimate voltage
- Computation
  - Kernel fault location takes ~1s for a normal feeder

Thank You

Questions?