Optimal Fault Location in Distribution Systems Using Distributed Disturbance Recordings

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After a fault occurs

1) Fault location

2) System restoration ("self healing grids")
   faulted component isolation & load restoration

3) Component reparation

Accurate fault location decreases customers interruption duration
Context: distribution fault location

Traditional methods
- Walking along the line
- Fault passage indicators
- Single-ended fault location (from the substation)

In a smart grid, more measurements are available
→ More sensors for better diagnosis
- Reduce number of possible fault location
- DG injection
- Increased accuracy
Objectives

Distributed V/I disturbance recordings
Substation’s relay, remote substation, recloser, DG relay, etc
Synchronized or not

How can I use these recordings for (optimal) fault location?

What accuracy is possible?
Content

- Fault location method with distributed V/I recordings
- Uncertainties in distribution systems
- Optimality of the algorithm
- Simulation results
Fault location method

From V and I phasors on one line segment

\[ d = f(V_s, I_s, \text{line charac}, \text{remote infeed}) \]

From both ends phasors is also possible:
Two-ended fault location
Fault location method

Transfer of the measurements through intermediate line segments and loads

Successive hops:

$V_s$  $V_r$  $I_r$  $I_l = f(V_r)$

Load model/
lateral model
Fault location method

Several recordings upstream the faulted line:
Aggregation via weighted least squares (+ synchronization)

\[ V = V@A = V@B \]
\[ I = Ia + Ib \]
Fault location method with several recordings

For every line segment: test $0 < d < 1$ and $R_f > 0$
Uncertainties in fault location

True networks parameters and measurements are never known
- Load estimation
- Phasor estimation
- Zero sequence parameters

Define confidence level on these quantities
→ Fault location is stochastic

Covariances are transferred with the mean values

Weighting the equations
Confidence level of the fault distance estimation (error propagation)
Optimality of the algorithm

Approach: use a maximum of available information

Take advantage of possible redundancies
  Two-ended fault location
  Measurement aggregation

Estimated errors are used as weights
Results

Arbitrary number of recordings

Theoretic accuracy of 100%

For some faults: several possible locations

Dependency on meters locations
Results

Error estimation: validation via Monte Carlo simulations

1 Ohm single-phase fault

Zero-mean normal noises on:
phasors (0.5%)
load admittances (33%)
Z1 (1%)
Z0(20%)
Results

Error estimation is precious for the utility

Impact of fault type and fault resistance

<table>
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<tr>
<th>Fault Type</th>
<th>Rf (Ohm)</th>
<th>Standard deviation (m) -calculated</th>
<th>Standard deviation (m)-Monte Carlo</th>
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</tr>
</tbody>
</table>

Zero-mean normal noises on:
- phasors (0.5%)
- load admittances (33%)
- Z1 (1%)
- Z0 (20%)

Line of 800 m

Can be used for sensitivity analysis as well
Conclusions

Fault location is important for the quality of supply

Why not use more measurements?
  Increases the observability and accuracy
  New algorithm is proposed using distributed V/I recordings

Uncertainties during the calculations must be considered