North American SynchroPhasor Initiative

NASPI Distribution Task Team
Technical Report

NASPI DisTT Use Case:
Fault Location

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Use Case

Synchronized measurements at multiple locations throughout a distribution system during a fault can aid in the location of the fault and expedite service restoration.

Background

The vast majority of faults originate in distribution systems. The traditional means of locating a fault on a distribution system is for a utility employee to travel along the feeder where a protective device has operated, or where customers have reported an outage, and search for the fault visually (in the case of overhead lines) or with an underground fault locator.

Reducing the extent of this manual inspection would reduce both outage duration and cost to the utility. A common, simple approach for this is to estimate the fault location using measurements of the fault current and voltage at the substation and a feeder impedance model. However, multiple combinations of fault location and impedance may lead to the same quantities being recorded at the substation. Furthermore, the contribution of distributed generation (DG) to fault current, which is not directly observable from the substation, can lead to errors in fault location.

The accuracy of fault location can be improved by collecting synchronized measurements of current and/or voltage at additional locations throughout the system. Several approaches based on search, optimization, and state estimation techniques have been demonstrated to locate faults using distributed measurements.

Examples

Multiple faults have been detected by µPMUs on distribution networks. An example is shown in Figure 1 [1]. As a first approximation, comparing the currents and voltage drops measured by multiple µPMUs distributed over a geographic area can indicate which of the µPMUs are upstream versus downstream of the fault location. It is also evident from the three-phase µPMU data which phases are affected by the fault. The specific fault location can then be computed from the set of measurements using a network model. Several algorithms have been demonstrated, using simulated synchrophasor data, to determine the fault location to within a few meters or a few tens of meters [2-4]. Although these algorithms have yet to be validated using real µPMU measurements, the accuracy remains promising when simulated measurement errors are added [3,4].

Data Requirements

Fault location requires synchronized time-series measurements with time resolution on the order of a cycle. While fault location methods using only voltage phasors [3] and only current phasors [4] have been demonstrated, for maximum location accuracy it is ideal to record both voltage and current, magnitude and phase. Since distributed generation can contribute significantly to fault current, measurements from the points of common coupling of DG installations are particularly advantageous. Knowledge of the errors introduced by current and potential transformers under high current and low voltage conditions is helpful to determine the uncertainty and confidence level in fault location.

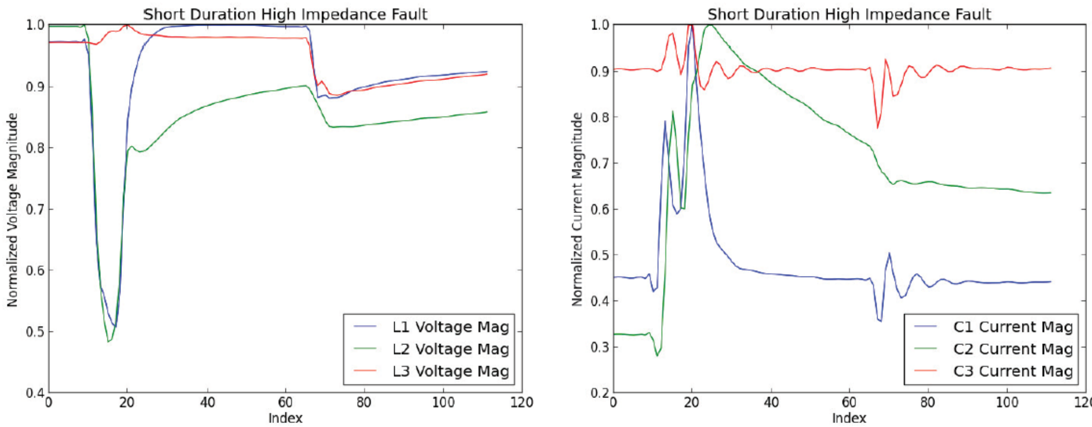

Figure 1: Three-phase voltage and current magnitude data streams collected by a µPMU during a high-impedance fault [1]. The time window displayed is one minute.

Development and Limitations

Tools and algorithms for this use case are at Technology Readiness Level (TRL) 6, ready for deployment in pilot-scale demonstrations. Algorithms await verification with empirical data.

References

[1] Y. Zhou, R. Arghandeh, I. Konstantakopoulos, S. Abdullah, A. von Meier, and C. Spanos, "Abnormal event detection with high resolution micro-PMU data." In 2016 Power Systems Computation Conference (PSCC), Genoa, 2016.

[2] J. Lee, "Automatic fault location on distribution networks using synchronized voltage phasor measurement units." In Proceedings of the ASME 2014 Power Conference, POWER2014-32231, Baltimore, MD, July 2014.

[3] S. Jamali and A. Bahmanyar, "A new fault location method for distribution networks using sparse measurements." *Electrical Power and Energy Systems* **81**, 459-468 (2016).

[4] C. Orozco-Henao, A. Bretas, R. Chouhy-Leborgne, A. Herrera-Orozco, and J. Marín-Quintero, "Active distribution network fault location methodology: A minimum fault reactance and Fibonacci search approach." *Electrical Power and Energy Systems* **84**, 232-241 (2017).