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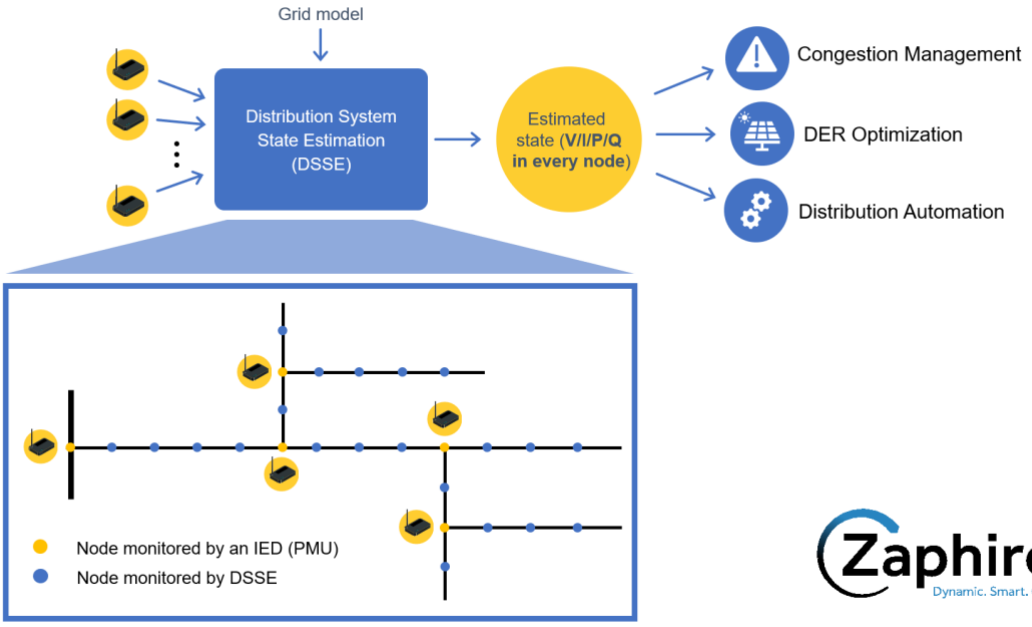
Distribution System State Estimation: Status-quo and Performance Improvement using Time-Synchronized Measurements



With the penetration of distributed generation and novel power-hungry loads, distribution utilities are increasing their efforts to manage actively their distribution networks. This is done through new investments in SCADA and ADMS systems as well as Intelligent Electronic Devices (IEDs). However, rising electricity rates and economic slowdowns have put a strain on the ability for distribution utilities to raise capital for new equipments.

To strike the right balance between cost and reliability, distribution utilities must reduce the cost of IED deployment while achieving optimal (ideally maximum) visibility coverage on power flows. In that sense, Distribution System State Estimation (DSSE) is being introduced in control rooms to obtain information about unmonitored grid nodes. DSSE is defined as an algorithmic process that computes the full grid-state (i.e. nodal voltages and currents in all nodes and all branch flows) while taking as an input multiple measurements of a subset of grid nodes.

The merit of a DSSE solution is evaluated based on three criterions: accuracy, coverage, and speed.

1) Accuracy is critical, as erroneous estimates can lead to undesired control/protective measures, which can have devastating consequences.

2) Coverage is important, as the goal of DSSE is to achieve complete visibility with limited amount of field measurement.
3) Speed is an application-dependent variable, a planning engineer might not need any real-time (e.g. sub-minute) information, but a closed-loop automation controller might require frequent periodic updates on the grid state.

A good DSSE solution must therefore require minimal field sensor, have an update rate sufficient to support the most demanding utility applications, and offer satisfactory accuracy under all operating conditions.

Time-synchronized measurements are beneficial for several grid applications. This is particularly true for control-room DSSE:

1) Non-synchronized measurements naturally introduce time inconsistencies in the DSSE measured inputs. Indeed, a delay of a few seconds can already cause inconsistency in the state estimation result, especially during dynamic events such as a cloud passing over PV generators or industrial motor starts. Time-synchronizing the measurements effectively enhances the accuracy of the state estimator.
2) Time-synchronized phasor measurements (i.e. synchrophasors) allow direct comparison of both magnitudes and phase-angles of measured quantities at different nodes/branches. Indeed, the phase-angle information is relevant for state-estimation as it gives more information with fewer measurements (e.g. phase-angles explain the direction of power-flows).
3) By using synchrophasors (i.e. time-synchronized phasor measurements), the use of linear algorithms to run state estimation becomes possible. As opposed to the non-linear, iterative method for state estimation, linear state estimation can be executed much faster (especially for complex networks) and guarantees convergence.

Zaphiro has developed its *SynchroGuard Linear State Estimator* to take advantage of time-synchronized measurements. It leverages synchrophasors but also uses linearized remote terminal unit measurements (i.e. nodal voltage and current magnitudes, power factor and/or active/reactive power injections). The solution has been field tested and proven to enhance grid operation through more accurate, faster, and cost-effective DSSE.

Learn more about our work at: www.zaphiro.ch