REAL TIME MONITORING OF DISTRIBUTION NETWORK

Akansha Pachpinde, Dr. HyungSeon Oh, Dr. Albert Titus, Dr. Jonathan Bird | Department of Electrical Engineering | University at Buffalo, The State University of New York.

Motivation

With increasing amount of Distributed Generation (solar and wind energy) being introduced in the power system, control of the grid has become even more complex. We desire improved flexibility, enhanced load control capabilities and stable operation of the entire power system including distribution network, which has very little monitoring and automation in place. This could only be realized if the Control Centre operator has a more accurate real-time picture of the network.

The following study focuses on a new design of Phasor Measurement Unit (PMU) for monitoring the state of the distribution system in real time. PMU is the only device that can measure magnitude and angle of voltages i.e. state of the system. Fiscal constraints amongst others have predominantly limited the installation and use of traditional PMUs. The proposed internet based PMU is considerably cheaper, does not require any major infrastructural changes and can revolutionize real time monitoring.

Current Scenario of Distribution Monitoring

- Provides only magnitude and not phase angle of voltages
- Provides synchronization in a time window of 2 seconds
- No monitoring present. Boolean data coming from fault indicators, sectionalizers and remote switches uploaded at the control center
- Supervisory Control and Data Acquisition System
- SCADA
- Distribution System Operator

Traditional Phasor Measurement Unit (PMU)

- PMU uses the global reference provided by GPS i.e. coordinated universal time (UTC) for measurements
- The measurements given by PMU are very precise. Total Vector Error (TVE) < 1% is allowed when error in magnitude, angle and time measurement are accounted for
- Unlike SCADA, PMU is based on TCP/IP protocol making integration and upgrading an easy task

But the average cost of installation of PMU technology is around $43,400/PMU

Internet based Phasor Measurement Unit design

- Internet time is synchronized using network Time Protocol (NTP). NTP uses a hierarchical, semi-layered system of time sources.
- The NTP algorithms on each computer interacts to construct a shortest-path spanning tree, to minimize the accumulated round-trip delay to the reference clock servers for all the clients.
- Phase Locked Loop (PLL) is used to lock the phase of the one pulse per second signal to the system. The multiplier then makes the sampling frequency a multiple of this clock frequency.

The Phase Locked Loop along with the multiplier can provide high frequency signal to the Analog to Digital converter. Oversampling the signal helps in compensating for the error in time measurement. It improves resolution, reduces noise and helps avoid aliasing and phase distortion. The building blocks of this system are not unfamiliar. Decades of experience in manufacturing and using them implicates that we have the necessary expertise to utilize them and the associated costs are low making implementation feasible.

Power flow equations

In power system operations:

\[ \frac{\Delta P_{ij}}{P_{ij}} \leq \left| \frac{\partial (\theta_i - \theta_j)}{\partial t} \right| \Delta t \]

\[ \frac{\Delta Q_{ij}}{Q_{ij}} \leq \left| \frac{G_{ij}}{B_{ij}} \frac{\partial (\theta_i - \theta_j)}{\partial t} \right| \Delta t \]

\[ \left| \frac{\partial (\theta_i - \theta_j)}{\partial t} \right| \leq 0.1, \quad \frac{G_{ij}}{B_{ij}} \leq 10^3 \quad \text{if } |\Delta t| \leq 1 \text{ms} \]

Future work will include:

- Building the system on printed circuit board
- Testing the system using simulation and hardware
- Cost estimation of fabricating such system taking into consideration the high sampling rate requirements in terms of A/D converter and memory
- Analyzing the time precision of the system and comparing it with traditional PMU and SCADA

The immediate benefits can be seen in terms of Fault location detection, Congestions Management, Power Flow management in the presence of DG, Validation of network reconfiguration etc. in the Distribution network.