Applications of Synchronized Phasor Measurement in ERCOT's State Estimator

Principal Investigators: Professors Surya Santoso and Mack Grady, University of Texas at Austin

Background: This proposal is written as an expansion of Task 2A in the description of the project titled "*Use of synchronized sampling in substation and system-wide applications.*"

Problem to be Solved: A state estimator is one of the most important tools in the reliable and economical operation of any power system. This is particularly true for ERCOT. The state estimator takes a set of actual telemetered measurements of bus voltages and load powers, plus transmission line active and reactive power flows, and then estimates all other voltages and power flows in the system. These values are then fed into loadflow and contingency analysis programs that evaluate approximately 500 contingencies every five minutes in an attempt to identify the critical system contingencies and weaknesses.

Ideally telemetered measurements should be time synchronized. Unfortunately, very little of such data are available widely if any today. A few synchronized phasor measurements taken at strategic points will enhance the accuracy of the state estimation. In addition, with a sufficient numbers of known synchronized state variables, observability of the state estimator can be increased and expanded. Therefore, this task will develop methodologies and technical guidelines for incorporating and making use of synchronized phasor measurements in existing ERCOT's state estimator. Potential benefits of synchronized phasor measurements will be investigated in terms of additional accuracy, robustness, and observability.

Additionally, power system topology determination in existing state estimators may have wrong indications due to measurement and/or communication problems. The transitions in the switching state taking place during the state estimator scan may create wrong determination of the system topology as well. Having GPS synchronized determination of the switching operations provides clear time relationship between various switching states and improves the ability to have correct determination of the switching state.

Approach for Solving the Problem: The ability to include voltage phase angles will greatly enhance the accuracy of the state estimator and increase network observability. It will also facilitate the identification of erroneous measurements, errors in transmission line parameters, and network topology changes such as taking lines out. Active power flow in a transmission line is proportional to the sine of the angular difference, thus having measured phase angles can confirm measurements of active power flows.

Presently, the load flow program predicts voltage phase angles. If a critical set of these phase angles can actually be measured, then their comparisons to load flow-predicted values would obviously add confidence to the modeling results by improving the accuracy of the state estimator. Furthermore, the phase angles could be incorporated into the state estimator itself to improve its accuracy by providing additional redundancy for the over-determined problem.

Our research would begin by comparing the GPS-synchronized phase angle measurements available stations in ERCOT with those predicted by ERCOT's state estimator and load flow programs, over a reasonable period of time and with different system loading conditions and interchange. Representative number of measurements from a few stations would suffice.

From this study, we would see how well the predictions and measurements agree. If the differences are significant, then we would develop a scaled version of a state estimator and use it on a reduced equivalent of ERCOT, perhaps 25-50 busses. ERCOT is expected to provide online diagram of electrical system, sampled outputs of ERCOT's state estimator (SE), and basic documentation of techniques employed in ERCOT SE. The scaled version of the state estimator will mimic the operation of ERCOT' SE.

Based on these data, we would work toward the proper methods for incorporating phase angles into the state estimation problem. The result would be a recommendation on how this procedure might be done on a larger scale by ERCOT or their vendor. Using the scaled version of the state estimator, we will also evaluate the requirements and methods for increasing the network observability, topology tracking, and increasing robustness of the state estimator. In developing the scaled-version and methods to enhance the state-estimator, we will focus on ERCOT operating environments and applications. The state estimation with GPS synchronized measurements will bring improvements both in the accuracy of analog measurements and in the topology determination leading to improved determination of power system states.

Deliverables: A detailed interim report for Year I describing methodology and recommendation for incorporating synchronized phasor measurements into existing ERCOT's state estimator.

A stand-alone proof-of-concept software in one of rapid prototyping software packages (Matlab, Mathematica, or Fortran) to be used for demonstrating the benefits and methodologies described in the report.

Expected Benefits to ERCOT: This proposed tasks of enabling ERCOT's state estimator with synchronized phasor measurement processing and analysis is expected to yield the following benefits:

- A methodology and technical recommendation for improved state estimator accuracy
- Increased measurement reliability and redundancy.
- Increased ability to maintain network observability
- Improved topology determination

One-Year Budget

Three half-time graduate research assistants, plus partial summer support for Dr. Santoso and Dr. Grady, plus supplies, travel, fringe benefits, and university overhead. The total requested budget is $139,000.