Advantages of Synchrophasor Measurements Over SCADA Measurements for Power System State Estimation

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Introduction

Power system state estimators filter power system measurements and estimate the power system state. This application note summarizes the advantages of replacing traditional SCADA measurements with synchrophasor measurements available in SEL relays for the state estimation process.

Traditional Power System State Estimation

The traditional approach to obtaining a power system state estimate uses a SCADA system to gather system data. SCADA systems obtain these data from meters, transducers, IEDs, and similar devices. This process guarantees that all the measurements are taken within a time window that is typically a few seconds long. The gathered data include status of breakers and switches, real and reactive power flows, and voltage magnitudes. When the system is in steady state, the measured quantities remain constant during the data-gathering process. Thus, the time skew between measurements does not introduce errors. The location of each measurement is chosen so that there are enough data to estimate the voltage magnitudes and angles at all buses with respect to an angle reference, in other words, to obtain complete observability of the system state. Real and reactive power measurements play an important role in the traditional approach to state estimation because these measurements, along with the branch parameters, are used to compute the angle difference between the buses at the ends of a branch.

Limitations of Traditional Power System State Estimation

Traditional state estimators can fail under two circumstances: when the system state is changing quickly and when critical data are missing. When the power system state is changing quickly, measurements taken in a time window of a few seconds are not consistent with each other. The inconsistencies between any two analog measurements are proportional to the time difference between the measurements and the rate at which the states are changing. Additionally, rapid changes in system states are often caused by changes in the topology of the system. When topology changes are undetected or happen during SCADA data polling, the estimation is likely to fail.

To illustrate the case of missing critical data, consider Figure 1. Assume that the voltage angle reference is located within Region A and that we have enough data to compute the angle differences at every branch within the two regions. However, there are no data available from the branch connecting the regions. In this situation, the angle differences at Region B cannot be used to obtain the bus voltage angles with respect to the angle reference in Region A. This limitation means that it is not possible to determine the state of the whole power system.

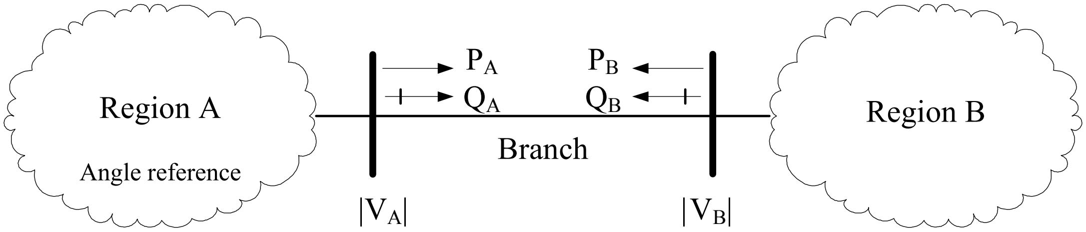
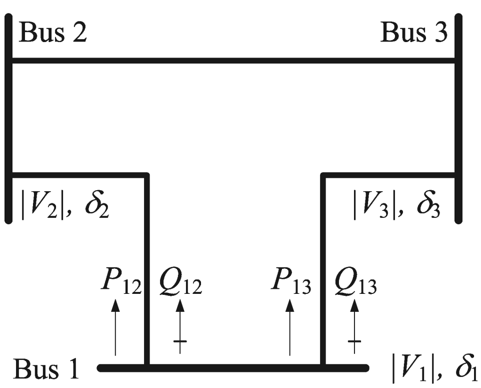


Figure 1 Two-region power system that excludes interconnecting branch critical measurements: $|V_A|$, $|V_B|$, P_A, P_B, Q_A, and Q_B

SOLUTION USING SYNCHROPHASOR MEASUREMENTS

Phasor measurement and control units (PMCUs), which are built into SEL relays, produce accurate timestamped measurements of voltage and current magnitude as well as phasor angles. They also report the status of breakers with timestamps synchronized to those of the measurements. Because PMCUs calculate synchrophasors with respect to a global angle reference, the number of critical measurements is less than when the state estimator uses SCADA measurements. Note that, as illustrated in Figure 1, having at least one PMCU measurement in each region allows us to refer all the voltage angles to the angle reference in Region A.

Another advantage of PMCU measurements for state estimation is that having direct angle measurements diminishes the amount of error introduced by inaccuracies in network parameters. For example, consider the three-bus power system shown in Figure 2. If PMCU data are available from each bus, all six states can be measured directly. If, on the other hand, SCADA data are available from the same three buses, only three states can be measured directly. The other three states, the voltage angles, have to be calculated using voltage measurements, real power measurements, reactive power measurements, network parameters, and an angle reference. Figure 2 shows SCADA measurements used to calculate the voltage angles. However, the quality of the results depends largely on the quality of the network parameters, which are not always accurate. PMCU measurements provide more direct and more accurate information than traditional SCADA measurements because PMCU measurements do not depend on network parameters.



	Measurements at Bus 1, Bus 2, and Bus 3	Computed
SCADA	$\lvert V_1\rvert, \lvert V_2\rvert, \lvert V_3\rvert, P_{12}, Q_{12}, P_{13}, Q_{13}$	δ_{12}, δ_{13}
PMCU	$\lvert V_1\rvert, \delta_1, \lvert V_2\rvert, \delta_2, \lvert V_3\rvert, \delta_3$	–

Figure 2 SCADA and PMCU direct state measurements and calculated states

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LAN2006-10