SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 USA
Phone: 509.332.1890 • Fax: 509.332.7990
www.selinc.com • info@selinc.com

Ten Synchrophasor Application Tips

Edmund O. Schweitzer, III
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Until recently, synchronized phasor measurements were available only from laboratory equipment or from expensive stand-alone phasor measurement units. The expense and need for separate equipment have limited the utility of synchrophasors.

Today, when you buy SEL meters, the SEL-421, SEL-451, and a growing number of SEL-300 series relays, you get synchronous phasor measurement capabilities for free! You can even get firmware upgrades for most of the SEL-300 series relays you own, for a nominal upgrade charge … further extending the reach of synchrophasors.

SEL Research and Development engineers worked hard to make synchrophasors ubiquitous, because there are so many things you can do, now that voltage and current measurements are precisely time-aligned. Thanks to microsecond-accurate GPS clocks (such as our own SEL-2407 and SEL-2401 clocks), precise time is available everywhere today. One microsecond corresponds to only about 0.02 electrical degree at 60 Hz, so phase errors in the measurements are mostly from instrument transformers.

Below, please find a list of ten tips for using synchronous phasor measurement information today. I believe that whether you test or commission protective systems, manage assets, operate control centers, develop models, or analyze power system events, you will find these tips immediately useful.

1. **Use synchronized phasor measurements from your SEL meters and relays to check your instrument transformers within your substation.**

   When the breakers are closed, all line and bus voltage transformers should agree in magnitude and phase. Now you can find out! Use the Meter PM command as a "vector voltmeter."

2. **Check your CT polarities, phasing, and ratio.**

   With a little load on the system, and all your relays synchronized, perform Kirchoff's Current Law around the bus, phase by phase. You will see any phasing, polarity, or ratio errors.

3. **Check CT and VT polarities, phasing, and ratio, line end to line end.**

   Take a phasor-measurement snapshot at each end of the line, with the Meter PM command, at the same instant of time. For a quick sensibility check, in most cases, you don't even need to take into account line parameters. Verify that phase A is really phase A on both ends, for your currents and voltages. Since you have synchronized phasors at both ends of the line, you can use the transmission line equations to do a very exact calculation. Investigate any errors. They can come from wrong line constants, errors in the instrument transformers, or in their connections.

4. **Analyze faults more thoroughly, and check your models.**

   Calculate infeeds from all sources, calculate fault resistance, and check zero-sequence parameters for lines and sources.

5. **Check your state estimator.**

   The state estimator estimates the magnitudes and angles of bus voltages. Is it accurate? Trigger measurements at several buses at the same instant, and compare your measurements with the estimates and find out! Also helps find bad SCADA data, when they don't agree.

6. **Don't have a state estimator? You now have something BETTER: direct measurement of the state!**

   Not only is it direct measurement, it is more frequent. You can get the measured state every second, versus an estimate every 1-10 minutes.

7. **Build automatic system self-checking schemes.**

   There are many examples. For instance, when two relays are on the same bus, or same instrument transformers, they should be measuring the same voltages and currents. In addition to the manual checks mentioned earlier, you can build automatic checks in your communications processors, to check routinely and let you know when something goes wrong ... with a relay, a connection, a test switch, or with instrument transformers. Take the difference between phasors, and visualize magnitude AND phase errors right away.

8. **Monitor angles across the transmission system.**

   Bring a few critical bus voltages and angles together at the control center, and display them for the operator. Ask the planners to make a chart that maps angle relationships into critical operating scenarios, so operators can easily use the data.

9. **Monitor angles between the transmission system and critical distribution buses.**

   Ask the planners to make a chart that relates the angles to voltage stability limits. The operators will then have a tool to visualize impending voltage collapse.

10. **Display oscillographic records collected by your synchronized SEL relays, from anywhere on your system, in perfect time-alignment!**

    Your SEL-5601 oscillographic software already supports synchrophasors!