IIT-Industry Collaboration – Synchrophasor Engineering Research and Training

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Project Description

Illinois Institute of Technology (IIT) has installed 12 Phasor Measurement Units (PMUs) on its main campus, home to the DOE-funded Perfect Power Microgrid. With the assistance of IIT Facilities, the PMU project has been gathering synchrophasor data from the 4 kV campus distribution network since summer 2012. In addition to IIT Facilities, the other project partners include Commonwealth Edison (ComEd) and Naperville utilities, as well as Schweitzer Engineering Laboratories (SEL). ComEd will provide anonymized synchrophasor data that is currently used by PJM transmission operators. Naperville will provide anonymized synchrophasor data that is currently used for distribution event analysis.

SEL has provided equipment for a synchrophasor test bench for undergraduate, graduate and practicing professional training courses. The hi-tech SEL hardware and software will attract students and expose them to the capabilities of synchrophasor technology. SEL donated hardware includes the following:

- Two SEL-351-6 PMU-enabled protection system relays
- One SEL-2407 GPS receiver
- One SEL-4000 Relay Test System (SEL Adaptive Multichannel Source (AMS) and SEL-5401 Test System Software)
- One SEL-5073 synchroWAVe Phasor Data Concentrator (PDC)
- One SEL-5078-2 sychroWAVe Central Software

New undergraduate laboratory modules have been built around the SEL equipment to help students master three-phase analysis, unbalanced faults, and transient stability. A new graduate short course has been created for an introduction to (i) IEEE C37.118, (ii) synchrophasor system hardware, and (iii) synchrophasor applications, such as validating dynamics models, assessing dynamic security, and detecting dynamic instabilities.

IIT Facilities, ComEd and Naperville have offered to provide tours of their substations and delivery networks. The students in this project will benefit from the utility experience, and the utilities will benefit from the student research work, including developing event analysis reports, assessing synchrophasor data collection infrastructure, performing data mining studies. Student research projects will begin this summer.

ComEd will provide the following synchrophasor data from four 345 kV substations, reported at 30 synchrophasors per second:

- Sub A, 345 kV Bus 1, Vag, Vbg, Vcg
- Sub A, 345 kV Bus 2, Vag, Vbg, Vcg
- Sub A, 345 kV Line 1, Ia, Ib, Ic
- Sub A, 345 kV Line 2, Ia, Ib, Ic
- Sub B, 345 kV Bus 1, Vag, Vbg, Vcg
- Sub B, 345 kV Bus 2, Vag, Vbg, Vcg
- Sub B, 345 kV Line 1, Ia, Ib, Ic
- Sub B, 345 kV Line 2, Ia, Ib, Ic
- Sub C, 345 kV Bus 1, Vag, Vbg, Vcg
- Sub D, 345 kV Bus 1, Vag, Vbg, Vcg

This data is currently used by the PJM Transmission Operator to maintain situational awareness in PJM West. It is also used by ComEd to perform event analysis. ComEd has provided some data to IIT to test our data transfer and storage processes.

City of Naperville will provide the following synchrophasor data from a 138 kV - 12 kV substation, reported at 10 synchrophasors per second:

- Sub A, 138 kV Bus 1, Vag, Vbg, Vcg
- Sub A, 12 kV Bus 1, Vag, Vbg, Vcg
- Sub A, 12 kV Line 1, Ia, Ib, Ic
- Sub A, 12 kV Line 2, Ia, Ib, Ic

This data is currently used by Naperville for event analysis. Naperville faced some trouble with their SEL gear. Originally, they had planned to provide synchrophasor data from their SEL-735 Power Quality and Revenue Meters. Based on Naperville's troubleshooting and discussions with SEL, a software update will be necessary, but it's not clear when it will be available from SEL. In the meantime, Naperville graciously agreed to provide synchrophasor data from another source, so that our project will not be negatively impacted. Naperville had planned an upgrade of some SEL 351 relays in a different 34.5 kV substation. That project has been accelerated and testing has begun at Naperville. Synchrophasor data (reported at 2 synchrophasors per second) is expected in this quarter.

IIT Facilities will provide the following synchrophasor data from a 4 kV substation, reported at 60 synchrophasors per second:

- Sub A, 4 kV Bus 1, Vag, Vbg, Vcg
- Sub A, 4 kV Bus 2, Vag, Vbg, Vcg
- Sub A, 4 kV Line 1, Ia, Ib, Ic
- Sub A, 4 kV Line 2, Ia, Ib, Ic
- Sub A, 4 kV Line 3, Ia, Ib, Ic
- Sub A, 4 kV Line 4, Ia, Ib, Ic
- Sub A, 4 kV Line 5, Ia, Ib, Ic
- Sub A, 4 kV Line 6, Ia, Ib, Ic

This data is currently used by IIT Facilities for event analysis. Beyond the synchrophasor-enabled substation, IIT has 11 other PMU installations, with a total of 288 analog channels captured at a rate of 60 synchrophasors per second. The Local Area Monitoring System (LAMS) captures 40 MB per channel per day, which is 10 GB of data per day, and nearly 4 TB of data per year. The PI is using this data for load dynamics model development.

Expected Research Outcomes

1. Utility partners will receive event analysis and data mining reports based on their synchrophasor data, which will help identify knowledge and research gaps.
2. Utility partners and IIT researchers will develop automated tools to analyze utility synchrophasor data in combination with traditional power system models, which could support generator model validation studies.
3. Utility partners and IIT researchers will study disturbances and associated system response synchrophasor data, which could assist load model validation projects.

Expected Education Outcomes

1. Undergraduate students will benefit from the hands-on synchrophasor laboratory experiences (three-phase power, waveforms vs. phasors, transformers, balanced short circuits, dynamic behavior, oscillations, transients, unbalanced faults).
2. More undergraduate students will be motivated to study power engineering.

3. Graduate students will benefit from the 2-credit (28 hours of instruction) short-course (IEEE C37.118, synchrophasor system hardware, and synchrophasor applications, such as validating dynamics models, assessing dynamic security, and detecting dynamic instabilities).
4. More graduate students will be motivated to study power engineering.

Opportunities for Possible Collaboration

1. Information sharing (synchrophasor data available online)
2. Resource sharing (visit IIT to run a test on the SEL-351 relays, or send me a COMTRADE file)
3. Expertise sharing (IIT has research strengths in power system dynamics, voltage stability, transient stability, microgrids, demand response, advanced distribution automation, autonomous agent-based control, energy storage, optimization, electric power markets, renewables, EV integration)