PROJECT SUMMARY

1 TITLE

Advancing Synchrophasor Applications and Training through Academic-Industry Collaborations

2 PRINCIPLE INVESTIGATORS

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3 CONTACT INFORMATION

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4 PROJECT DESCRIPTION

A. Project Objectives

Through the collaboration among the University of Wyoming, Colorado State University and Montana Tech of the University of Montana, which are from three different states in the rocky mountain region sharing the same grid interconnection, and their collaborations with diverse industry partners including transmission grid operators, equipment vendors, local utilities and national research labs, this project will result in up-to-date education and research in different aspects of synchrophasor technology. This collaboration will also help prepare the future workforce in power engineering at multiple dimensions with expertise in synchrophasor technology and applications. Specifically, we want to carry on this project to achieve the following objectives:

- Expose students to the operations of synchrophasor measurements through experiments;
- Prepare the students for the challenges in modern power system and smart gird implementation by curriculum update;
- Attract and invite experts in other areas such as signal processing and computational methods to contribute to the power engineering society by incorporating synchrophasor data analysis in existing non-power courses;
- Promote interdisciplinary education and training by developing brand new courses;
- Strengthen the academic-industry collaborations through student internship;
- Broaden impact of this academic-industry and academic collaborations by presenting tutorials/workshops/short courses at annual meetings or industry visit; and
- Train future power engineering leaders by mentoring undergraduate and graduate in research.

B. Planned Activities

In this project, with the support from the industry participants on data, equipment, and potential internship and employment opportunities, we will put collaborative efforts in both education and research to train and provide future workforce in power engineering.

Curriculum Development: We plan to 1) build phasor measurement unit (PMU) testing system for class demonstration and lab experiments; 2) update current power engineering courses by incorporating the most up-to-date synchrophasor technique and its applications in power system monitoring and control; 3) incorporate the synchrophasor data analysis in existing signal processing courses; 4)

Table 1: Equipment List for PMU Testing System

Qty	Device	Description
1	SEL-4000	Relay Test System
2	SEL-351A	Protective Relay with Synchrophasor Capability
1	SEL-787	Transformer Protection Relay
1	SEL-3373	Phasor Data Concentrator
1	SEL-3620	Security Gateway

develop new interdisciplinary courses on signal processing for power systems and wide-area monitoring system.

Research and Student Mentorship: In order to prepare future leaders in power engineering, we will also put efforts in mentoring both undergraduate and graduate students in research, with selected topics such as: 1) power system state estimation with bad-data analysis; 2) power system event detection by synchrophasor data analysis; and 3) synchrophasor data storage and high-performance computing.

Broader Services to the Society: We will extend the impact of our efforts to the industry partners and further to the entire power engineering society by seminars during on-site visit, student internships and tutorials/Webinar/workshops.

C. Industry Partners

Various companies and utilities will participate in this project in various aspects. The Bonneville Power Administration (BPA) will participant in this project as the provider of the synchrophasor data collected from the grid. In particular, test data on the power system in different environment will be available to conduct research on event detection and evaluation. As major equipment vendor, the Schweitzer Engineering Laboratories (SEL) will donate PMU devices for in-class hands-on PMU testing and potentially provide internship positions and future employments for trained students. Rocky Mountain Power (as our local utility), Sandia National Laboratories (as a major research lab in power systems) and Alstom (as major grid operator), will support our proposed projects by potentially providing internship opportunities. All of the collaborators will also provide insight into both educational and research topics from a power industry perspective.

D. Progress Achieved to Date

Up to date, the team has worked on various aspects for the curriculum development and submitted a couple of publications. Specifically,

- At the University of Wyoming, the PIs have
  - Added basic introduction to synchrophasor-based wide-area monitoring system for electric power grid to an undergraduate required course, EE 3510 Energy Systems.
  - Developed a new interdisciplinary course on signal processing in power systems that includes basic signal processing techniques to analyze synchrophasor data (now being offered);
  - Started updating the current power systems course by including several lectures on synchrophasor and its applications in power flow analysis (now being offered and new contents will be taught later this semester); and
  - Published one conference paper on power system frequency estimation and submitted one journal paper on bad data processing for synchrophasor systems, all jointly prepared with PIs in the Colorado State University.
- At Montana Tech of the University of Montana, the PIs have

  - Finalized the list of equipment to be used to develop the instructional and test facilities and contacted SEL to donate all equipment needed to all three participating universities (see Table 1 for the list). Equipment has been received at Montana Tech and Colorado State University and is expected at the University of Wyoming before summer;
  - Drafted the test plan for PMU dynamic measurements;
  - Begun drafting the synchrophasor instructional materials; and
  - Organized historic synchrophasor data to be used in course homework/projects and shared with the other two universities.

- At the Colorado State University, the PIs have
  - Developed a new interdisciplinary course on signal processing in power systems that includes basic signal processing techniques to analyze synchrophasor data (now being offered and available online); and
  - Published one conference paper on power system frequency estimation and submitted one journal paper on bad data processing for synchrophasor systems, all jointly prepared with PIs in the University of Wyoming.

5 EXPECTED EDUCATION AND RESEARCH OUTCOMES

By the planned educational activities such as building PMU demonstration system and curriculum update and development, we will provide improved training for both undergraduate and graduate students with improvement in both breadth and depth. Specifically, we expect more students to be attracted to work in the area of power engineering and bring interdisciplinary knowledge into the development of future power grid. In addition, as a team with diverse specializations, we are also looking forward to successful research outcomes that help achieve the maximum utilization of the synchrophasor technique for power systems. Specifically, by our planned research activities, we expect to provide algorithms to apply synchrophasor data analysis to various power system applications such as state estimation and event analysis, and evaluate current synchrophasor data storage schemes and develop more efficient and effective ones. Furthermore, the academic-industry collaboration and the collaborations among universities in the same area in this project can serve as a prototype and inspire more similar efforts to meet the demand of more knowledgeable workforce training and interdisciplinary research on synchrophasor and other topics in next-generation power grid.

6 AREAS FOR POTENTIAL COLLABORATIONS

The setup of our PMU testing system can be shared among different universities. In addition, the data generated from our testbed can be shared with other projects to develop synchrophasor data compression and storage schemes. All course-related materials can be shared for collaborations on curriculum development.