EPRI | ELECTRIC POWER RESEARCH INSTITUTE

LEVERAGING INDUSTRY RESEARCH TO EDUCATE A FUTURE ELECTRIC GRID WORKFORCE

HIGH-LEVEL RESEARCH QUESTIONS

- Identify and incorporate high-level power systems/ grid related research already being performed within the partnering institutions of the GridEd collaboration into GEARED educational products.
- Develop new and revised courses in regular undergraduate and graduate programs, as well as in a variety of custom tailored short courses, tutorials, workshops, symposia, and other methods of instructional and experiential delivery.
- Set priorities in consultation with utilities for the benefit of all aspects of their diverse workforce.
- Stimulate student interest in the field of electric power engineering through connection with student organization in the power and energy field as well as establish activities at participating university in support of power engineering.

KEY TAKEAWAYS

- Established a platform to sustain funding, via subscriptions, to a broad workforce development program and professional training courses.
- Elevated awareness at electric utilities that training and education (T&E), including building relationships with universities, is important.
- Provided avenues that enhanced student engagement and career opportunities in the electric power industry.

OPEN QUESTONS

- Education and training for university students and professionals at the intersection of digital systems and power systems.
- How to effectively integrate a virtual laboratory experience into the distance learning format as the laboratory experience is a distinguishing feature of an engineer.
- How to adequately train power engineers and complete their engineering education considering pressures to decrease the number of hours required to obtain a degree.

COMPLETED TASKS AND MILESTONES

- ☑ 1: Developed an evaluation plan and provide quantitative metrics including number topics, courses, students, and employment outcomes to the GEARED national network administrator.
- ☑ 2a: Identified utility training needs through a power systems curriculum gap assessment and continuous professional training topic prioritization surveys.
- ☑ 2b: Extended the university network to include 34 Affiliates sponsored by utility participants
- ☑ 3: Developed 29 new and revised under/graduate courses in power systems at 7 Partner universities touching 2,763 students during the 5-year effort.
- ☑ 4: Delivered 40 professional training courses to more than 940 participants from more than 72 organizations on 15 prioritized topics.
- ☑ 5: Developed open-access e-learning content for a 2-semester course in basic power systems.
- ☑ 6: Developed a strategy and funding mechanisms for consortium self-sustainability.
- ☑ 7: Developed and implemented numerous K-12, community engagement and outreach programs.
- ☑ 8: Developed and maintained public engagement through a website (http://grided.epri.com)
- ☑ 9: Created and maintained a student scholar presence including innovation boards, over 20 student design projects, networking teleconferences, and sharing of employment opportunities.
- ☑ 10: Executed 6 regional student-centered conferences in collaboration with the GEARED network.
- ☑ 11: Managed project including coordination meetings, re-staffing, and reporting requirements.

	DE-EE0006338 (GEARED)		DE-EE0007328 (STEP)	
	Cumulative Spend	Budget Remaining	Cumulative Spend	Budget Remaining
Fed Share	$4,200,001	$-	$997,154	$2,846
Cost Share	$2,584,297	$-	$394,939	$-

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EXECUTIVE SUMMARY

GridEd is a collaborative educational initiative consisting of the Electric Power Research Institute, seven (7) Partner universities (Arizona State University, Clarkson University, Georgia Institute of Technology, Portland State University, University of California–Riverside, University of North Carolina-Charlotte, and University of Puerto Rico Mayaguez), and participating utility and industry sponsors. This educational initiative focuses on developing and training the next generation of power engineers so they can help shape the electric grid of the future by anticipating and fulfilling the needs of changing electric industry requirements. GridEd is leveraging electric industry research to educate a future electric grid workforce by empowering new and continuing education students, not only to become competent and well-informed engineers, but also to participate and influence major technological, social, and policy decisions that address critical global challenges.

The history for organizing the collaborative stems from the U.S. Department of Energy's award to EPRI and its team through two initiatives -- Grid Engineering for Accelerated Renewable Energy Deployment (GEARED) and Solar Training and Education (T&E) for Professionals (STEP). These two cooperative agreements resulted in an eastern U.S. initiative (the original effort) and subsequently a western U.S. initiative. The respective names for these efforts are GridEd-East and GridEd-West. Collectively, the project is called GridEd, and all resources and products are shared between the two efforts. The differentiation has been maintained to reflect regional differences in the philosophies, as well as organizing student activities where time shifts demand separate organizational efforts.

GridEd's activities are centered around four core pillars:

- Enhancement of university power systems engineering curricula,
- Professional development and training for a diverse electric industry workforce,
- Stimulating both university and K-12 students to join the movement for the next generation of power engineers,
- Improve workforce development efforts in the electric utility industry

To this end, GridEd has defined and developed educational products that support the full life cycle of employment as illustrated in Figure 1. The robust GridEd training program leverages decades of research results on integrating renewable energy sources and other new technologies into the grid. The resulting training material comes in many forms suited to specifically educate university students—the next generation of electric industry employees—as well as existing employees. Further, student-oriented activities have been designed to encourage selection of the electric power industry as a preferred career path beginning with K-12 and extending to the university environment. The priorities of the program are established in consultation with utility and electric industry participants for the benefit and development of all aspects of their diverse workforce. Execution of program activities is coordinated with the GEARED National Network Administrator (award DE-EE0006342) and other GEARED institutes.

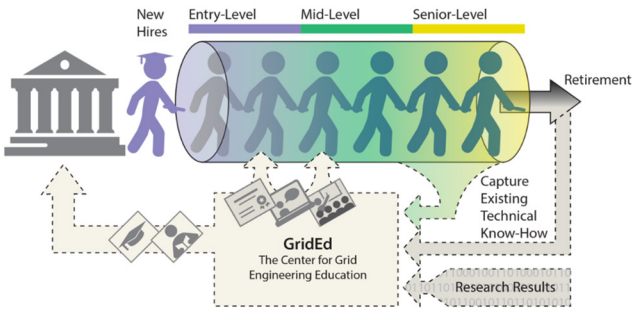

Figure 1 – GridEd Concept Illustration

Accomplishments of GridEd

University Curricula – GridEd-East and GridEd-West Partner universities identified gaps in power engineering education through a university curriculum review. GridEd Partner universities have developed ten (10) new courses and nineteen (19) modified courses at the undergraduate and graduate levels, impacting a total of 2,763 students. The 29 different course topics range from basic undergraduate courses in power systems analysis, power electronics, and electrical energy systems to more advanced graduate level courses including internet of things (IOT) for Grid Modernization, Market Operation of Power Systems, and Power Quality.

Professional Development and Training – To date, 942 attendees have participated in 40 short courses and workshops covering 15 topics through GridEd's professional training program. Course topics were chosen based on annual surveys of the advisory body and feedback from bi-annual advisory meetings. Further, a free and open access e-Learning course which covers two semester's worth of basic power systems was developed based on direction from utility advisors.

Student Engagement and Outreach – GridEd's Student Innovation Board (SIB) has consisted of 13 universities and 41 student leaders from GridEd Partner and Affiliate universities. GridEd has participated in the planning and execution of 8 different conferences where the GEARED effort has had a presence to increase student participation. Multiple outreach activities have been conducted including the development of an energy pathway curriculum for high school students from Georgia Tech, Discover Engineers Day at UNCC, seminars for high schools at UPRM, in addition to educational materials for middle-school students and outreach through microgrid research at Clarkson. Other engagements have included webcasts to share best practices for internships and co-ops, sharing opportunities for internships and co-ops, free discussion sessions, and student design projects.

Human Resources (HR) – A committee composed of HR professionals from 16 utility advisors was assembled to share leading practices related to recruitment and retention of their diverse future workforce. Workforce development has emerged as a critical need for the electric industry as competition for high caliber staff increases. Monthly teleconferences had focused discussion on topics including recruitment, development, retention, public outreach, and engaging underrepresented audiences which include minorities, women, veterans and other underserved labor markets.

LEVERAGING THE INDUSTRY

GridEd has been anchored by 25 utility organizations and their associated advisors. Since the utility industry is the primary recipient of the university power engineering product, GridEd has sought its guidance and direction on shaping the future power engineering workforce. The new T&E products are based on current research among partnering entities, while benchmarking against industry's perceived needs. Beyond the development of T&E materials, GridEd is focused on enhancing relationships between utilities and universities as a sustaining requirement.

One of the most exciting aspects of GridEd is the extension of the university network through our utility sponsors to establish Affiliate universities and to emphasize power engineering education at the regional and local levels. GridEd has reached a total of 34 Affiliate universities, each of which have been nominated by a utility sponsor. Affiliate university professors receive access to course materials which have been developed by GridEd Partner universities to aid in the development and enhancement of their own power systems curriculum. Three university workshops were held to train Affiliate university professors on the availed course materials and to provide a venue for professors to share leading practices on curriculum modifications, student projects, laboratories, and distance learning. Further, Affiliate universities have attended GridEd short courses, where they learned about the latest issues facing the electric industry; and using the foundational pieces from these courses, mathematics and modeling can be added to create semester-long courses at their universities. Finally, through their affiliation with GridEd, students at Affiliate universities have had additional opportunities to engage in power engineering through the GridEd Student Innovation Board and GEARED student conferences.

The GridEd network has evolved into a strong national effort. Its breadth has touched 46 utilities (either through membership or participation in short courses) which operate in 43 U.S. states and several internationally as represented in Figure 2. Also shown are the locations of universities that make up the GridEd program.

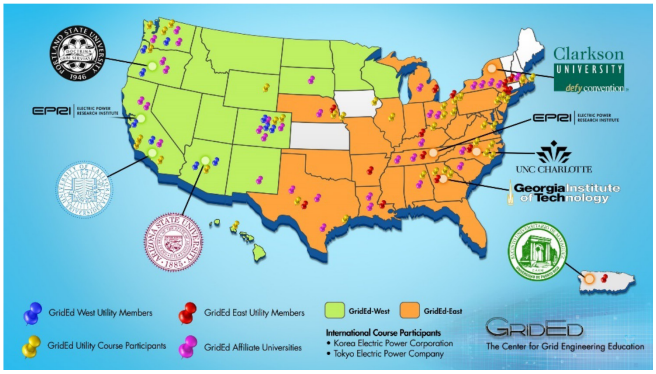

Figure 2 – Map of GridEd Participants

MOTIVATION FOR PROJECT AND RESEARCH QUESTIONS ADDRESSED

The Electric Power Research Institute and a strong collaborative team consisting of seven Partner universities and twenty-five electric utilities, as a member of the national GEARED Network, have sought to leverage utility industry R&D results with power engineering educational expertise of a team of universities to meet the GEARED project goals. The primary goal of this project has been to address the educational needs of the next generation of power engineers with particular focus on distributed solar and other distributed generation, storage and demand-response devices that change fundamental properties of the nation's electrical grid.

The future electricity grid will need to be more automated and flexible to effectively integrate distributed renewable sources and all other energy resources. Further, it must accommodate new technologies and solutions for performance monitoring, energy management, operation and control, planning and reliability assessment. However, trends in the nation's power engineering workforce have not kept pace relative to the increasing complexity and significant changes expected in electric power distribution grid. The GridEd effort addresses the needs of a future workforce at different career stages, with outreach to the communities and high schools, and providing basic education to the public via open access courses and efforts to boost interest in power engineering careers of K-12 students.

As a consortium, all organizational members of EPRI collaborate in advancing clean energy deployment and electric grid operations, aligning academic research and student/faculty activities with industry and electric utility needs in the US economy. GridEd members collaborate with other consortia within the national GEARED network and with the National Network Administrator to conduct student-centered research conferences and share curricula, develop and offer short course materials, and disseminate/share individual faculty and student research results and publications throughout all GEARED participants. The project team has aspired to empower new and continuing education students to become not only competent and well-informed engineers, but also participate and influence major technological, social, and policy decisions that address critical global challenges.

While GridEd's utility partners participate in GridEd by training professional staff in appropriate GEARED-supported "short courses" and hiring students from this program through internships or full-time employment, the project team has reached out beyond formal partner organizations to recruit other utility participants in the educational programs and include them in the collaboration. The project team has also developed a sustainability plan to financially support high value activities beyond the initially scheduled five-year project.

Project Objectives

GridEd seeks to define and develop educational offerings focused on power systems engineering for all levels: from high school students, the beneficiaries of outreach, through undergraduate and graduate students, practicing engineers pursuing professional development, to mature and experienced engineers who are keen on understanding and developing skills to design, plan, operate, and protect evolving energy systems, especially distributed generation and its integration into the traditional electricity grid. Core objectives of GridEd include:

- Identify and incorporate high-level power systems/grid related research already being performed within the partnering institutions of the GridEd collaboration into GEARED educational products.
- Develop new and revised courses in regular undergraduate and graduate programs, as well as in a variety of custom tailored short courses, tutorials, workshops, symposia, and other methods of instructional and experiential delivery.
- Set priorities in consultation with utility members for the benefit and development of all aspects of their diverse workforce.
- Stimulate student interest in the field of electric power engineering through connection with student organization in the power and energy field as well as

establish activities at participating university in support of power engineering.

- Examine workforce needs through engaging the HRs personnel in the electric utility industry.

PROJECT TEAM

Electric Power Research Institute (EPRI)

EPRI manages GridEd activities which bring together current research and development (R&D) results, university educational processes, and utility and industry needs. EPRI also serves as a resource by using the outputs of its R&D process from solar, renewable, and distribution engineering work to provide a basis from which to develop a variety of T&E materials. Roles and responsibilities include:

- Project lead and financial manager.
- Utility and industry interface/engagement – Establishes the mechanism to engage utilities and industry within GridEd. Organizes workshops and conference calls to identify gaps and needs in terms of both near term and long-term planning while sharing curriculum and training materials with utility and industry participants.
- Develops new and uses existing mechanisms to make particular EPRI research available to GridEd for development of curriculum and training course materials.
- Uses EPRI roadmaps, annual research portfolios, summer seminars, research advisory and council feedback to set the direction of GridEd activities in terms of identifying need for new curriculum and/or new training materials.

Principal Investigator
Tom Reddoch – treddoch@epri.com

University Partners

Universities are vital to the sustainable operations of GridEd due to the substantial resources required for the preparation and dissemination of T&E materials. Additionally, the capability of universities to transfer ongoing cutting-edge research into educational programs is essential to enhancing engineers' skill sets by training them on the latest technology required to manage and operate the future grid. University participants receive commitments via subcontracts with EPRI as part of GridEd. They are supported by GridEd and have roles as primary developers of the curriculum and provide early-stage delivery of the curriculum. Roles and responsibilities include:

- Lead development of curriculum and training materials.
- Develop and incorporate new courses into traditional power system/engineering programs and/or update the course content of existing programs.
- Develop and offer new post-graduate level power system courses focusing on PV and other distributed renewable technology.
- Develop and offer continuing education courses for professional utility engineers.
- Develop open-source/ online/ electronic materials as part of tech transfer.
- Execute training.
- Bring new findings from continuing research into curriculum and/or new training materials.

Georgia Institute of Technology

Georgia Institute of Technology has supported the development of courses and topical materials needed for a portfolio of undergraduate, graduate, and short courses on similar subjects. Power program enhancements have benefited engineering workforce and services to Southeastern utilities and industry members with strong ties to Georgia Tech and the National Electric Energy Testing, Research and Applications Center (NEETRAC). Georgia Tech has led three of GridEd's initiatives including Training and Dissemination, Evaluation, Communication, Engagement and Outreach.

Principal Investigator
Sakis Meliopoulos – sakis.m@gatech.edu

University of North Carolina, Charlotte

The University of North Carolina at Charlotte (UNCC) has developed and is offering new and modified power engineering classes, some of which are offered as distance education classes such that working professionals can enroll in these courses. In addition, a graduate certificate program in power systems has been offered for the first time. Bringing strong research and industry ties through the Energy Production and Infrastructure Center (EPIC), UNCC is leading curriculum development in graduate programs for GridEd. UNCC is also leading student engagement activities for GridEd-East such as the Student Innovative Board and Student Conferences for GridEd.

Principal Investigator
Badrul Chowdhury – bchowdhu@uncc.edu

Clarkson University

Clarkson University is a nationally recognized research university for undergraduates with select graduate programs in signature areas of academic excellence directed toward the world's pressing issues, including electric power engineering. As members of GridEd, Clarkson faculty have developed new power engineering course content at both the undergraduate and graduate levels. Clarkson has also expanded its professional Master's degree program for practicing power engineers and has created a graduate level certificate program in power engineering. Short courses, webinars, and online courses for electric power professionals have also been provided.

Principal Investigator
Tom Ortmeyer – tortmeye@clarkson.edu

University of Puerto Rico, Mayaguez

The University of Puerto Rico, Mayaguez (UPRM) graduates more Hispanic Electrical Engineers than any other U.S. school and is among the top five institution graduating power engineers in the U.S. Through new online professional engineering development short courses and seminars, UPRM is providing practicing engineers with training on traditional power systems as well as power systems with significant presence of distributed technologies. UPRM has led the e-Learning development for GridEd.

Principal Investigator
Agustin Irizarry-Rivera – agustin@ece.uprm.edu

Arizona State University

Arizona State University's electric power engineering program is one of the largest, most comprehensive, and well-known power engineering educational programs in the United States. ASU has led curriculum development efforts through revising and offering instructional materials for its online Master's degree program with courses re-engineered to address the integration of renewable resources in the electric grid. ASU has also developed a short course on critical topics in Power Quality.

Principal Investigator
Vijay Vittal – vijay.vittal@asu.edu

University of California, Riverside

Power Engineering is one of the premier programs at UC Riverside (UCR) and their engineering program was ranked in the top quartile nationally by the 2010 National Research Council. UCR recently launched the Sustainable Integrated Grid Initiative (SIGI), one of the largest smart grid projects of its kind in the state. The initiative represents an investment of $7 million and has been developed specifically to research the integration of intermittent renewable energy, energy storage, and all types of electric and hybrid electric vehicles. As part of GridEd, UCR has developed new graduate level courses in power systems and has offered a short course on Predictive Analytics for Electric Power Distribution Systems.

Principal Investigator
Nanpeng (Eric) Yu – nyu@ece.ucr.edu

Portland State University

Portland State University (PSU) has established power engineering tracks within their BS EE and MS ECE degree programs, directly benefitting the regional electric power industry by providing engineering education, new talent and R&D opportunities. PSU's power programs feature design-focused power engineering teaching labs that provide students within opportunities to gain hands-on experience with modern industry-standard equipment. PSU has led the Student Innovation Board (SIB) for GridEd-West. PSU has also developed new design-centered courses at the graduate and undergraduate levels which focus on advanced motors/generators, distributed assets, storage, utility communications, and renewable generation.

Principal Investigator
Bob Bass – rbass2@pdx.edu

Electric Utilities

Electric utilities and industry advisors are critical to the overall success of GridEd, as the central objective is to provide education and training for engineers who are responsible for the design and operation of the grid of the future. The specification of skills and knowledge requirements for future engineers is best prescribed by the solicitors of such employees. As such, GridEd's advisory structure comprised of all electric utility industry professionals directs the GridEd effort. Roles and responsibilities include:

- Act as hands on advisors to ensure the GridEd activity is beneficial and useful for the electric utility industry now and in the future – nominate/engage the right personnel to serve as an advisor and participant in GridEd.

- Offer their senior/experienced personnel to contribute within GridEd:
  - Help identify gaps and needs by providing research, operation, and business questions and concerns
  - Work as subject matter experts where applicable
  - Serve as instructors when appropriate
- Send their junior and mid-level engineers to the topic specific short courses and workshops.
- Allow the use of their existing training facilities for hands-on activities built into the short courses and workshops.
- Support the consortia after the DOE project period ends.

Over the 5-year project period, there have been 25 different electric utility members of GridEd as summarized in Table 1 below.

Table 1 – GridEd Utility Advisors from 2014–2018

GridEd-East		GridEd-West	
Arkansas Electric Cooperative	2014–2015	Arizona Public Service	2016–2018
CPS Energy	2014–2018	Bonneville Power Administration	2016–2018
Central Hudson	2014–2018	Pacific Gas & Electric	2016–2017
ConEdison	2014–2018	Portland General Electric	2016–2018
DTE Energy	2014	Tri-State Generation & Transmission	2016–2018
Duke Energy	2014–2018	Salt River Project	2014–2018
EcoElectrica	2016	Snohomish Public Utility District	2016–2018
Entergy	2014–2018	Southern California Edison	2016–2018
First Energy	2014–2018	Western Area Power Administration	2016–2018
Louisville Gas & Electric and Kentucky Utilities	2014–2018	Xcel Energy	2016–2018
Lincoln Electric System	2014–2018		
National Grid	2014–2016		
New York Power Authority	2014–2018		
Tennessee Valley Authority	2018		
Southern Company	2014–2018		

Affiliate Universities

GridEd seeks to extend its university network by reaching and emphasizing power engineering education at the regional and local levels through Affiliate University membership. Affiliate Universities are sponsored by utility and industry advisors. Curriculum and course content developed by GridEd team partners is being dispersed to Affiliate Universities at a regional and local level. Additionally, students attending Affiliate Universities are able to engage in GEARED activities via the GridEd Student Innovation Board and GEARED student conferences. Roles and responsibilities for each Affiliate University include:

- Attend tech transfer events and seminars
- Provide feedback and input on activities, including curriculum review and core course content and material
- Send students to GEARED student conferences
- Enlist student representatives in the GridEd Student Innovation Board.

Over the 5-year project period, there have been 34 different Affiliate university members of GridEd as summarized in Table 2.

Table 2 – GridEd Utility Advisors from 2014–2018

GridEd-East		GridEd-West	
Buffalo State University	2014–2018	California Polytechnic State University	2016–2017
Case Western Reserve University	2014–2018	Colorado School of Mines	2016–2018
Clemson University	2014–2018	Colorado State University	2018
Lawrence Technological University	2014	New Mexico State University	2014–2018
Louisiana State University	2014–2018	Oregon Institute of Technology	2016–2018
North Carolina State University	2014–2018	Oregon State University	2016–2018
Rensselear Polytechnic Institute	2014–2018	Sacramento State University	2016–2017
State University of NY, New Paltz	2014–2018	South Dakota State University	2018
Syracuse University	2014–2018	University of California, Irvine	2016–2018
University of Akron	2014–2018	University of California, Los Angeles	2016–2018
University of Alabama-Birmingham	2014–2018	University of Colorado, Denver	2016–2018
University of Louisville	2014–2018	Washington State University, Pullman	2016–2018
University of Nebraska	2014–2018	Washington State University, Vancouver	2016–2018
University of New Orleans	2014–2018	West Texas A&M University	2016–2018
University of Memphis	2018	Western Washington University	2016–2018
University of Tennessee, Chattanooga	2018		
University of Texas, San Antonio	2014–2018		
University of the Incarnate Word	2014–2018		
Worcester Polytechnic Institute	2014–2018		

SIGNIFICANT RESULTS AND KEY TAKEAWAYS

University Curriculum

The GridEd-East team conducted a curriculum review and inventory at each of the four universities to assess desired modifications to each university's curriculum. This review, along with institutional education goals, led to new and/or revised courses at each institution. Select findings from the initial review and inventory include (among others):

- A requirement for a power area course for all electrical engineering undergraduates at each GridEd-East Partner university.
- Relatively new course additions on non-traditional energy sources at each GridEd-East Partner university covering a broad range of content.
- A two-semester sequence of courses in power systems at each GridEd-East Partner university (a three-semester sequence exists at UPRM).
- A wide variety of advanced courses at the graduate level are offered in three traditional categories/tracks: (1) Electric Power Systems, (2) Electric Machines and Drives, and (3) Power Electronics.
- Between the four GridEd-East Partner universities, there are 15 courses offered in the Electric Power Systems track, two in the Electric Machines/Drives track, and three in the Power Electronics track.

To date, GridEd Partner universities have developed ten (10) new courses and nineteen (19) modified courses. These courses include undergraduate, graduate, and combined undergraduate/graduate coursework as described below in Figure 3. In addition to developing new and revised courses, PSU also redesigned and expanded the power systems protection teaching laboratory by re-writing all of the protection laboratory content and expanding the number of protection and power systems teaching racks.

There have been 2,763 students impacted by these new and revised courses. The number of students who enrolled in one of the courses a GridEd Partner university either revised or newly created has increased year over year as shown in Figure 4. The large increase in 2016 was primarily caused by two factors. First, in 2016, Georgia Tech revised an undergraduate course called Electric Energy Systems which has enrollments of over 100 students in each semester. Second, the addition of three universities in GridEd West added more courses in 2016. The slight drop in enrollments in 2018 was due to slightly lower enrollments in several of the larger courses, the missing of reporting of summer courses for one of the GridEd East universities.

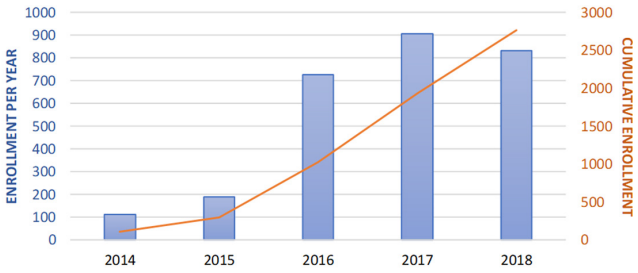

Figure 4 – Student Enrollments in GridEd New or Revised Courses

Power Engineering Emphasis	Undergraduate Courses	Combined Undergraduate / Graduate Courses	Graduate Courses
Electric Power System Analysis	•Analytical Methods for Power Systems •Design of Transmission and Distribution Systems •Power System Analysis •Power System Engineering •Power Systems I •Senior Design Projects (x2)	•Electric Power Distribution Systems II •Energy Markets •Power Systems Protection	•Advanced Topics in Energy Power Systems •Deregulated Power Systems •Electric Power Distribution Systems •IoT for Grid Modernization •Market Operation of Power Systems •Power System Dynamics •Power System Planning •Power System Reliability •Power System Stability •Power System Steady State and Market Analysis •Power Quality
Machines & Drives	•Industry Design Processes		
Power Electronics	•Power Electronics •Power Electronics and Power Management	•Utility Applications of Power Electronics	•Advanced Power Electronics •Renewable Electric Energy Systems
New Energy Systems	•Electrical Energy Systems •Introduction to Energy Systems		•Distributed Energy Resources

Figure 3 – GridEd New and Revised Undergraduate and Graduate Courses

Curriculum Sharing and Network Design

The GridEd approach to expanding the knowledge base through a network is to provide ready access to state-of-the-art training materials to a wide university audience. The electric utility industry has a historical practice of hiring from local universities. GridEd seeks to create and improve partnerships between the utilities and their regional universities. To date, GridEd has built a national team around 25 utilities and 41 universities to implement this strategy. Although the plan is national, it is executed on a local basis through the utility and its local universities.

The program begins with a utility that sponsors up to two universities (Affiliates) to join the GridEd program. Universities cannot join unilaterally; they must have a utility sponsor. This approach assures the connectivity between the utility and the university – the key strategy for sustainability. Regular activities, as illustrated in Figure 5, were provided to accelerate the value propositions for Affiliate universities.

Figure 5 – Summary of Affiliate University Activities

Each Affiliate university is given ready access to GridEd materials. This is provided through our SharePoint website, where managed access requires Affiliates to be active in the GridEd process. This disciplined approach assures quality engagement and allows utilities to gauge their effectiveness at building the relationship with the Affiliate. The value proposition for Affiliate universities includes numerous opportunities, none more valuable than their students getting full access to all GridEd and GEARED student activities. Also, Affiliate faculty have access to the full short course program of GridEd. The Affiliates are listed on the GridEd website thereby acquiring the branding value from the national programmatic effort.

EPRI has a vast reservoir of research results and reports on a plethora of topics related to electricity generation, transmission, distribution, end-use and environmental impacts. Many of these reports are free and available to the public, including Affiliate universities. Relevant reports and research results can be found through www.epri.com. Of the reports that are fee-based, EPRI often avails many of these to U.S. universities at a discounted price of $250 for copyright only reports and $450 for software and licensed reports. Several universities have taken advantage of this pricing, using books and reports published by EPRI as textbooks. However, universities are not guaranteed this price for all reports as they must be approved by an EPRI VP or Director Delegate. Information on this program may be obtained through askepri@epri.com.

Train the Trainer Workshops with Affiliate Universities

GridEd established a national university network and a university course sharing program for electric power systems knowledge through its Affiliate university program. The strategy has been to extend electric power systems knowledge, especially at the basic level, to a large part of the unserved university community. The Affiliate university program is described in more detail elsewhere in this report. A key aspect of this program is the sharing of academic curricula and materials developed by the Partner universities with the Affiliate universities. Affiliate universities in both GridEd-East and GridEd-West will gain access to the entire body of materials developed by the seven (7) Partner universities of GridEd to include newly created courses and revised portions of courses. Materials such as PowerPoint slides, lecture notes, and problem sets are being uploaded to an internal GridEd SharePoint site which serves as the main repository within the GridEd initiative. This allows Affiliate universities who are considering adding new courses or modifying existing courses in their respective programs to access course materials that may help in the development and revision of their own courses.

Professional Training Program

A key element of the GridEd strategy is to address T&E needs for active professionals in the electric industry. As such, in 2014, GridEd launched a four-course tutorial short course series as a first step in addressing the educational needs of practicing engineers. The tutorial series represented an effort to link multiple courses as a complete package directed at the effects of DER devices and systems on the electric distribution system. Most participants failed to enroll in the entire series and instead elected to take the various courses separately. The concept of a linked series was dropped, and subsequently

only individual courses are offered. A library of courses has been developed covering fifteen (15) short course topics and one workshop. These courses focus on fundamentals and help participants understand analytical procedures, industry practices, and emerging technologies for electric power system planning, design, and operation of present and future electric grids.

Through an annual survey that is administered to GridEd utility sponsors, a gap assessment of utility industry needs has been obtained. This survey has been conducted annually for the first three years of the program thereby providing a profile of interests over time. Surveys have been conducted in both 2015 and 2016 with the expansion to GridEd-West, enabling a broader sampling and the ability to obtain regional variances in preferences and priorities. Figure 6 shows the survey results for 2016.

The most recent survey results show some major differences less agreement on prioritization of short course topics between eastern and western utilities when compared to prior survey results. Utility priorities were benched-marked against university opinions which also demonstrated clear differences. Potential additional courses not yet in the GridEd library include Data Communications Technologies and Applications and Micro-Grid Concepts and Designs.

The 2014 short course program had four (4) courses which were presented to 59 attendees who received a total of 848 professional development hours. Through 2018, 942 attendees have participated in 40 short courses covering fifteen (15) different topics and one workshop through the GridEd Short Course Professional Training Program. All GridEd short courses are open to the public and registration is accessible through the GridEd website as courses become available. Courses have been offered in a variety of formats including live in-person, online, and hybrid.

A summary of the total attendees in each course provided through 2018 is shown in Figure 7. The short course program has become popular as course offerings have expanded. The most popular courses have included DG Interconnection on Radial Distribution Systems, Energy Storage Technologies, Applications, and Integration, and Applications of Smart Inverter Technology.

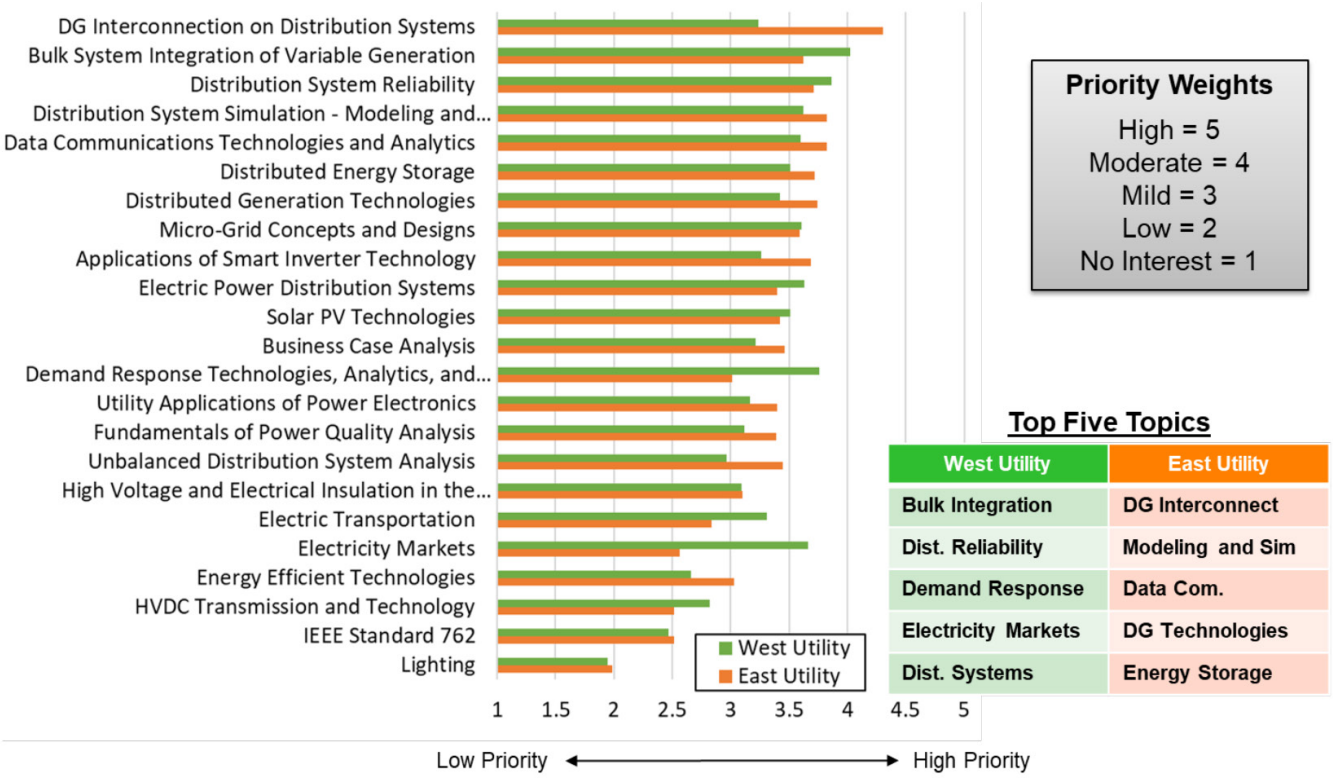

Figure 6 – Summary of Affiliate University Activities

Notes: Some utilities provided one response to the survey after summarizing internal prioritizations while other utilities elected to have multiple people respond to the survey. Results provided herein represent a single "weighted" response for each utility.

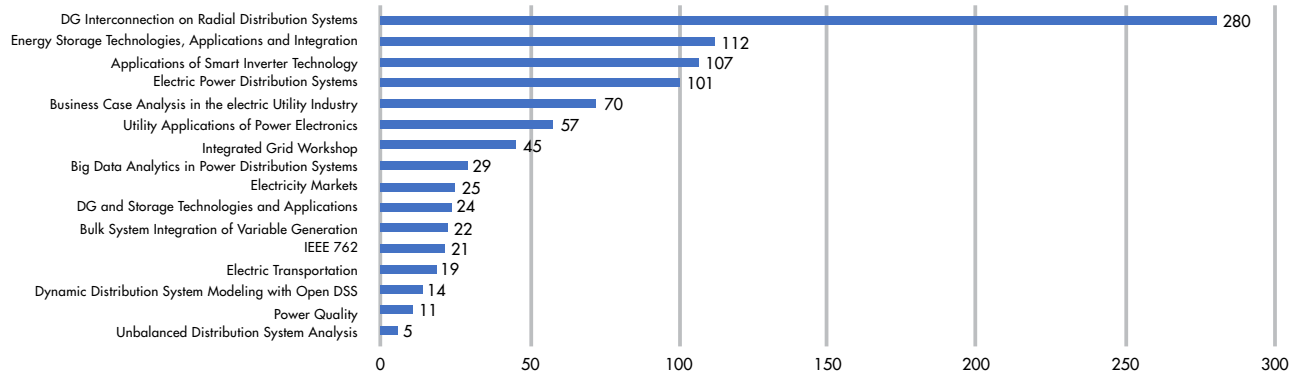

Figure 7 – GridEd Professional Training Course Enrollments by Course, 2014–2018

As shown in Figure 8, annual enrollments have been much higher in the last two years than in prior years. Though enrollments dipped slightly in 2016 and 2018 given a lower number of course offerings due to management distractions of expanding the overall GridEd effort, there has been growth in the number of people receiving training throughout this program.

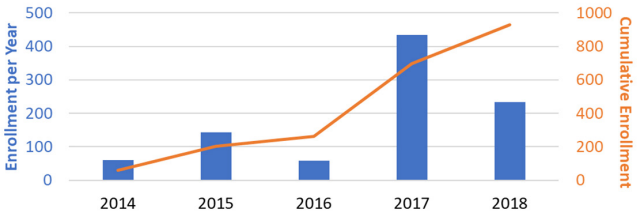

Figure 8 – GridEd Professional Training Course Enrollments by Year, 2014–2018

The GridEd short course program is also made available to both our Partner and Affiliate universities at no cost when unused slots are available in courses. Many of the courses are based on state-of-the-art research and are taught by EPRI experts. One of the most exciting aspects of this program has been the conversion of short courses into full university curriculum offerings. Case Western University (an Affiliate) and Clarkson University (a Partner) faculty attended short courses and then integrated course content into their respective electric power programs.

e-Learning

The traditional classroom setting is under serious review as advancing technology is opening doorways to alternative teaching arrangements. GridEd has been exploring various new classroom teaching methods as a way of improving classroom effectiveness, looking at larger and wider audiences, and trying to understand the economics that new techniques offer. The e-learning environment is certainly one new option with great promise. The e-learning environment is one in which course content is delivered to a remote audience from where the teacher is delivering the material. The various venues might include prerecorded sessions or live interactive ones where remote students can query the instructor, hear other students, and join the class as a "live" participant.

GridEd has evaluated various software packages for presenting lecture materials through e-learning. Since GridEd engages multiple organizations it is developing standards for "recording" instructional materials in a consistent manner to ensure accessibility by everyone. Presently, no single software has been chosen, rather an evolving practice continues as new options are developed.

An Electronic Version of a Two-Semester Course in Basic Power Systems

The strategic direction and program content of GridEd's e-learning activities were developed using the advice of electric utility advisors. From the outset, utility advisors have given GridEd consistent messaging – they need training materials which address the fundamentals of electric power systems. Such materials should be broadly accessible as in the GridEd website. In the advisor's view, many electrical engineers hired in recent years by their respective companies had either limited or no training in electric power. Utilities are seeking ways to advance those employees' familiarity with the fundamentals of electric power systems. A statement from an IEEE PES PEEC Survey from 2015 affirms the observations discussed at many GridEd advisory meetings and webcasts, that many graduates lack a background in electric power.

"About 70% of Canadian universities have mandatory courses in power engineering for all engineering students while 46% of US universities have mandatory courses

for all students. The percentage of universities requiring a power course in the electrical engineering undergraduate curriculum decreased from an all-time high of about 80% in 1994 to about 65% in 2001-02 to about 59% in 2005-06. Almost all universities have undergraduate elective courses in power engineering. Those universities that do not offer elective courses do offer mandatory courses. Mandatory course for all students in a special track, minor, or certificate are offered at 30% of the Canadian universities and 43% of the US universities."[1]

Utilities are having to invest heavily in bringing new hires up to typical standard of the electric industry before they can deploy the principles and practices followed at their utility. These results pointed to a need for an electric power systems "101" course for the new hires in the fundamentals of being an electric power engineer which was absent from their university education. This led to the formation of a two-semester course equivalent, known as the "Basic Power Course" that addressed most aspects of fundamental power system analysis.

The four GridEd-East Partner universities have developed power point slides and recorded lectures for this course and GridEd has made these materials broadly available to the public through its website. The materials made available are nominally 80 modules, ranging in length from 20 minutes to 1 hour, with lectures on topics mutually agreed upon by the four GridEd-East Partner universities. Each university is responsible for covering a quarter of the material. The textbook chosen for the course is: Glover, J.D., Overbye T. and Sarma, M. (2016) Power System Analysis and Design. Sixth Edition. Cengage Learning, Stamford, CT, USA. An abbreviated syllabus is provided below in Table 3.

The complete course can be summarized as a traditional two-semester course in electric power systems. The first course provides the fundamentals of electric power systems analysis as it relates to components of electric power systems (generation, transmission, distribution, and electricity demand) and their interaction along with models that allow analysis of single-phase and three-phase power systems under steady state operation. Whereas, the second course provides the fundamentals of electric power systems for analytics on such topics as the power flow problem in three-phase power systems, power systems under fault conditions, and the fundamentals of power system dynamics and stability analysis.

After completing the course sequence, the student should have the tools and practice to analyze and understand balanced single- and three-phase power systems under normal and abnormal (faulted) conditions. This college-level course will prepare engineering students, and practicing engineers, in the fundamentals of electric power system analysis. All students are expected to have an engineering background to include college calculus II, differential equations, an electromagnetics course, and circuit analysis (Laplace, Fourier transforms, network equations).

1 Electric Power Engineering Education Resources: 2015-16 US and Canadian University Survey Results. Report from the Power and Energy Education Committee of the IEEE Power & Energy Society. November 2017.

Table 3 – Abbreviated Syllabus for GridEd's Basic Power Course

Part 1	Part 2
Energy, apparent, real and reactive power, power factor, Review of phasors	Review of phasors, balanced three phase; per unit analysis and transformers
Single-phase circuit analysis	Admittance Matrix Formulation and Network Calculations
Efficiency and regulation	Power Flow Analysis; Iterative Solutions to nonlinear Algebraic Equations: Newton-Raphson. The Power-Flow Problem. Power-Flow Solution by Newton-Raphson. Control of Power Flow. Sparsity Techniques. Fast Decoupled Power Flow.
Per unit	Intro to fault analysis: Impedance Matrix Formulation and Network Calculations
Balanced Three-phase circuit analysis, Single-phase equivalent circuits, efficiency and regulation; Per unit 3 phase analysis	Symmetrical Components
One-line diagram representation of three-phase circuits	Short circuit – unloaded synchronous machine. power system three-phase short circuit, circuit breaker and fuse selection; and unsymmetrical faults
Transformer connections and Phase Shift. Per-Unit Equivalent Circuits of Balanced Three-Phase Two-Winding Transformers. Three-Winding Transformers. Autotransformers. Transformers with Off-Nominal Turns Ratios	Definition of stability, system dynamic performance and criteria for system dynamic performance; Types of stability studies Causes of major blackouts. Real-Time Dynamic Security Assessment: Fast Simulation and Modeling Applied to Emergency Outage Security of the Grid.
Transmission lines classification; models and parameters	Synchronous Machine Classical Model
	The swing equation; Synchronizing power and natural frequencies of oscillations
	The Equal Area Criterion
	Multi-machine dynamics and stability studies; Digital simulation of multi-machine systems

Human Resources Committee

In pursuit of understanding T&E needs through industry engagement, the GridEd team identified another gap related to T&E. Electric utilities have been struggling to recruit qualified electric power engineers for some time. Often, utilities hire electrical engineers; however, there still is a gap in experience and skill to support the needs of this ever-changing industry. Further, retention of engineering staff is a challenge that many in the industry are dealing with. Most electric utility HR departments have recognized that T&E is key to both recruiting and retaining engineers and other technical staff.

Today's engineer is seeking career growth in a world where flexibility at work and a focus on professional development is a growing trend. As a part of working with electric utilities, recognizing that a utility's HR strategy is key to developing and sustaining a workforce, GridEd established an HR Committee composed of representatives from utility partners with the purpose of examining workforce development needs and best practices as it relates to the electric power engineers for the electric utility industry.

The HR committee met periodically to discuss opportunities in workforce development through a shared exchange of ideas and best practices. Primary targets for topics of discussion include recruiting, employee development, retention, and outreach to the general working public as well as reaching out to underrepresented audiences which include minorities, women, and veterans. A summary of key findings[2] from the committee include:

- ***Recruiting:*** Hiring managers need to understand what type of individual is needed for their respective role. Working with hiring managers to recruit individuals who have learning agility is important to addressing the fast paced electric utility industry.
- ***Retention:*** This is an evolving issue for utilities as they are accustomed to hiring lifetime employees. Employees in general are far more mobile in today's society for a variety reasons. Professional development could be a key to retention as well as a focus on structured knowledge transfer programs. Professional growth within a company is critical. Knowing a plan for upward mobility could be critical.
- ***Millennials:*** This generation of engineers have a completely different view about work/life balance. Recognize there will be a tendency for engineers to move often and frequently. Utilities need a plan to back fill gaps created by early movement of the "millennial engineer." Further, it is important to recognize the priorities of millennials and other generations and how your company must be structured to both recruit and retain this diverse set of employees.
- ***Succession Planning:*** Identifying future leadership in a company has always been a challenge. Aside from dealing with millennials and potential retirees, understanding how the digital age changes the way utilities should think about succession planning is important. Utilities will need to meet with their HR leaders and develop competencies that will meet the needs of the organization today and in the future.
- ***Roles of HR and Technical Staff:*** A partnership is required between HR and technical staff and leadership to accomplish the topics listed. HR plays an important role in working with leadership to develop a corporate plan that is strategic in how an organization will attract and retain talent. In the end, it is about winning the talent war.

Student Engagement

Student Innovation Boards and Other Student Activities

To help address both technological and workforce challenges associated with the exponential growth in distributed resources, GridEd, with the guidance of DOE and the GEARED Executive Committee, assembled a Student Innovation Board (SIB) which was comprised of 13 universities, with 41 undergraduate and graduate student participants. The SIB for GridEd-East was led by Valentina Cecchi at UNCC while Bob Bass of PSU led the efforts for GridEd-West. The aim of GridEd's SIB was to apply fresh approaches and unfettered creative thinking by creating a network of student leaders whose focus is on power engineering in order to benefit utilities, supporting industry, and consumers. A sample of several students on GridEd's SIB is shown in Figure 9.

The responsibilities of the GridEd SIB have been to:

- Participate in planning, evaluation and assessment activities of GridEd objectives, research, development, analytical capability, curriculum and academic program development, course availability, and quality improvement options;

2 A full report of GridEd's HR committee findings can be found at *GridEd Human Resources Working Committee Report.* EPRI. Palo Alto, CA. 2019. 3002016750.

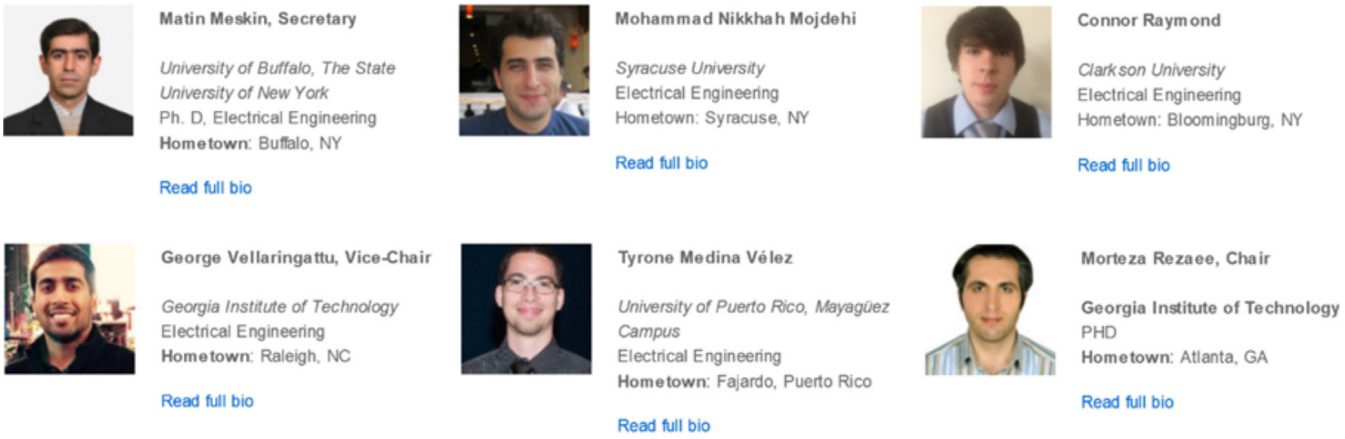

Figure 9 – Sample of GridEd Student Innovation Board Members

- Serve as communication liaison among GridEd and students and student organizations on campus;
- Advocate and promote student participation in GridEd activities such as GridEd senior design competitions, multidisciplinary engineering projects, graduate and undergraduate research projects, paper and/or poster presentations at technical and professional society meetings.

Several highlights of the SIB activities include conference calls; participation in student conferences such as NAPS; DistribuTECH; hosting and presenting at IEEE PES roundtable meeting on GEARED activities and the GridEd program; utility field trips; GEARED/GridEd presentations at each institution with a goal of increased campus visibility and awareness of GridEd activities, especially among students; bi-monthly webinars organized on rotation by SIB at each university; and free discussion sessions. A GridEd-East SIB Chair, Vice-Chair and Secretary were elected by the students, and officers were re-confirmed and updated as needed to account for graduating students.

Conference Participation

Industry conferences are a great venue to:

- Promote the mission of GEARED/GridEd to other industry leaders and experts;
- Provide students valuable experience to learn about the latest trends, technologies, and issues emerging in the industry;
- Enrich a network of students, experts, and leaders involved the GEARED/GridEd initiative by providing a venue to convene in-person.

The GridEd network has participated in a wide variety of activities in a range of industry conferences as summarized below.

North American Power Symposium (NAPS) – October, 2015 – Charlotte, NC

UNCC was instrumental in helping coordinate a unique poster expo which allowed 47 undergraduate and graduate students an opportunity to present projects that would have otherwise not been accepted as a paper in the NAPS conference. Additionally, a GEARED Student Innovation Board networking event allows students an opportunity to meet and network in person. SIB member, Mónica Mercado, a senior undergraduate student from the University of Puerto Rico – Mayaguez won 1st Prize with a poster titled "Residential Grid-Tied Photovoltaic Energy System Design in Puerto Rico."

DistribuTECH – February, 2016 – Orlando, FL

GridEd sent several students to participate in the student poster session which was organized by PennWell Corporation (then owner of DistribuTECH), Siemens AG, and other GEARED consortia. Additionally, several video clips were submitted to Siemens who prepared an impressive promotional video about the GEARED initiative which was displayed at the conference and has been posted to the main page of the GridEd website.

IEEE Power and Energy Society (PES) General Meeting – July, 2016 – Boston, MA

GridEd participated in the planning for a GEARED panel session as part of the Power Engineering Education Committee (PEEC) track in order to promote the innovations in power engineering education that had resulted from the GEARED program to the industry at

large. Five (5) GridEd representatives gave presentations as part of the session on topics including workforce development for the utility industry, GEARED University Curricula, Multi-Institutional Course Sharing Agreements, and Professional Training Programs.

Solar Power International (SPI) – September, 2016 – Las Vegas, NV

Tom Reddoch (EPRI), Phil Matthews (Talent Acquisition Manager from Southern California Edison – a GridEd-West utility member), and Joe Sarubbi (Interstate Renewable Energy Council [IREC]) made a presentation entitled "What Keeps Electric Utility Industry HR Managers Awake at Night?" This was an introduction to the concept that a combination of technical staff, HR, and corporate management commitment is needed to hire, retain, and train the next generation of the utility workforce. Further, a faculty member and student from the University of California, Riverside were able to attend the conference for free with the help of IREC which negotiated several passes from the Smart Electric Power Alliance (SEPA) who was the host for the meeting.

North American Power Symposium (NAPS) – September, 2016 – Denver, CO

GridEd sent three (3) faculty and a student representative who participated in the student organized speaking engagement as well as GEARED planning meeting which discussed what constitutes a power systems engineer and the idea of creating a textbook focused on microgrids.

DistribuTECH – February, 2017 – San Diego, CA

GridEd secured one (1) of the seven (7) Mega Panel Sessions at the DistribuTECH conference in 2017 at San Diego, CA. This session was on the topic of educating, developing, and hiring the next generation of power engineers. A panel composed of leaders from utilities in the GridEd-West consortia discussed some of the challenges facing the industry as well as how several utility initiatives are addressing these challenges. Further, several GridEd representatives are helped plan a student poster session and potentially other student activities at this conference.

DistribuTECH – February, 2018 – San Antonio, TX

GridEd supported other GEARED consortia to host 47 student posters in the annual student event and worked with the local university (GridEd Affiliate university – University of Texas, San Antonio) to provide a student tour of a local solar facility. The highlight of the meeting was the industry panel session at the student assembly space provided by DistribuTech for student activities. Three utility representatives presented on what does it mean to work for a utility. A panel of young engineers served as early career direction for the students. After the panel, a Q and A forum was planned as well as a networking event. It gave students an opportunity to query actual utility employees on a day at a utility.

DistribuTECH – February, 2019 – New Orleans, LA

GridEd again supported other GEARED consortia to host 53 student posters and worked with Entergy to provide a student tour of a local solar+storage facility. The significance of this conference was the milestone that the student poster exhibit moved from the hallway to the Conference Exhibit floor. This reflects the value that the new DistribuTECH ownership (Clarion Events acquired DistribuTECH form PennWell Corporation) has placed on the importance of connecting students with the electric industry. To reinforce these principles, DistribuTECH has added a space on entrepreneurial start-up companies next to student area. These companies would otherwise not have fiscal resources to participate. This move to the Exhibit floor is major and is a consequence of 5-years of engagement with the GEARED project.

Student Design/R&D Projects

Student design and R&D projects are a valuable way for students to gain practical experience and develop the skills necessary to prepare them to meet the future challenges of the evolving power system. GridEd has supported student design projects through a variety of activities, several of which are highlighted below.

Georgia Tech's "Portable Photovoltaic Generation System for Educational Purposes"

This is a two-year design project through Georgia Tech's Opportunity Research Scholars (ORS) Program. The ORS program matches undergraduate students with graduate students to work on research projects together. This particular project involved developing a portable PV system that can be transported to classrooms and other events to be used as an educational demonstration of PV technology. The portable PV unit is being used in the classroom (ECE3072) – Electrical Energy Systems as well as demonstrations to high school students across the Atlanta metropolitan area.

University of North Carolina-Charlotte's Senior Design Competitions

UNCC holds a senior capstone design exposition every year for all engineering design projects (Illustrated in Figure 10). As part of this expo, industry sponsors are brought in to interact with students and provide them feedback. Further, a group of reviewers including professors and industry evaluate the projects and awards are made for the students. Several projects related to GEARED included two Duke Energy-sponsored projects, one focused on designing a Distribution Management System for the UNCC campus grid, the other on Volt-Var control for distribution systems. In addition, an SEL-sponsored project on automated reconfiguration and load management for the UNCC campus and an EPRI-sponsored project on DC microgrid are included as well.

University of Puerto Rico - Design of a Community PV System

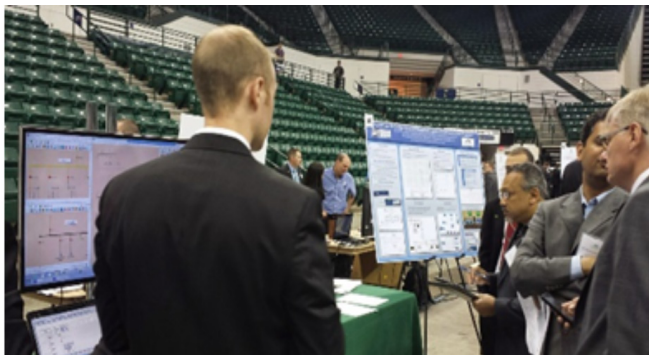

Figure 10 – Design Project Presentation at UNCC (left) and a Design Project Working Group at UPRM (right)

In calendar years 2015, 2016, 2018, and 2019, undergraduate students worked on a capstone design project where they re-designed the electrical wiring of the community center building, accounting for a planned expansion and building renovation. The design included load calculation, sizing of conductors and conduits, feeder calculation, interior and exterior lighting design, a rooftop PV system and a back-up generator. Students also performed a preliminary assessment of the possibility of converting the community into a "solar community" using the "behind the meter model" in which the community PV system is composed of rooftop systems installed at individual homes. In this scheme, benefits and responsibilities were shared among participants of the solar community. Students prepared initial PV designs for the dwellings, rooftop PV systems, and analyzed two PV penetration scenarios. This Community Solar Outreach Projects strives to go beyond technology and to achieve sustainable energy through self-reliance, community development and engagement. A working group of students is illustrated in Figure 10.

Clarkson University – Photovoltaic Senior Design Team

A capstone group at Clarkson completed their design of a photovoltaic installation for the university's crew team building. This building previously had no electric supply. The PV system is providing electric power for lighting, electronic device charging, and an inverter for small hand tools. Their goal was to complete the design, obtain the necessary approvals, and purchase and install the equipment. The goal was met. Also, the team conducted a cost/benefit evaluation of LED lighting for one of the Adirondack Mountain Club's buildings.

EPRI's Support of Undergraduate Design Projects for Affiliate Universities

In the Fall of 2016, EPRI began offering financial support (up to $5k per project) for undergraduate design projects which are related to engineering challenges associated with the generation, transmission, distribution, or end use of electric power. These awards are eligible for Affiliate universities of GridEd in order to help stimulate additional focus on power engineering at the undergraduate level. Projects were selected through an open solicitation process. A list of these student projects is provided in Table 4 below and have been shared with the broader industry and university community through GridEd's website.

Table 4 – GridEd Affiliate University Undergraduate Deign Projects

University	Undergraduate Design Project Title
Buffalo State	Enhancement of Transactive Energy Test Bed Related to Microgrid with Deployment of Synchrophasors for Protection, Monitoring and Control
Rensselaer Polytechnic Institute	Estimation of Behind-Meter Renewable Generation from Power Consumption Data - Phase 2
University of Colorado Denver	Energy Management System
Western Washington University	Distribution System Fault Location Identification: A Quickest Change Approach
Buffalo State	Testbed for Transactive Energy and its Effects on the Distribution System and Protective Devices Settings
California Polytechnic State University	Microgrid System Protection
Colorado School of Mines	Advancement in Electric Drives and Motor Design as Applied to the Steel Industry and Electrical System Design Calculations
University of California, Irvine	Evaluation of Power-to-Gas for the State of California in Various Renewable Energy Scenarios
West Texas A&M University	Photovoltaic Battery Charger for Residential Microgrid
North Carolina State University	Distributed Energy Generation and Storage System Design
Oregon Institute of Technology	Three-Phase Variable Frequency Motor Controller & Inverter Implemented using Space Vector Pulse Width Modulation on a Field Programmable Gate Array
Oregon Institute of Technology	Second Life Battery Characterization
Rensselaer Polytechnic Institute	Estimation of Behind-Meter Renewable Generation from Power Consumption Data
University of Louisville	An AC Microgrid Test Bed for Exposure to Power Systems Concepts
Western Washington University	A Statistical Framework for Real-Time Event Detection in Power Systems

Student Employment Preparedness

Preparing students for the workforce is a core objective of GEARED. Beyond updating curricula and building a student network of leaders focused on electric power engineering, the GridEd consortia has helped prepare students in its network by promoting their engagement in summer internships and multi-year co-op opportunities. GridEd has engaged two main activities to promote these opportunities:

- ***Internship, Co-Op and Full- Time Job Opportunities Web Portal:*** EPRI created a portal on the GridEd website to serve as a source for students to find multiple internship and job opportunities among the GridEd network. The portal includes links to utility advisor's Career pages and EPRI's Careers page, as well as a link to the IEEE PES Careers page which hosts an even larger portal for internship, co-op, and full-time job opportunities. The website portal has been advertised through the SIB network to make students aware of this resource.
- ***Notification of Internship and Scholarship Opportunities:*** One of the main benefits of having a network of student leaders focused on the area of electric power engineering is that it enhances our ability to communicate opportunities for employment and scholarships to a wide range of students who are directly interested in those opportunities. For example, EPRI helps to run the Energy Storage Association's STUDIO conference which provides a select number of scholarships to students interested in attending the conference. In 2015, EPRI was able to use the GridEd SIB network to promote those scholarships to students and all scholarships were eventually filled.

K-12 Outreach

GridEd's K-12 outreach initiatives have included a variety of innovative methods for piquing student interest. This includes the development of classroom curriculum and training materials, PV demonstrations, and special programs devoted to hands-on engineering activities, to community outreach using engineering expertise, systems and technology in poor and impoverished areas, and creating a lasting impression on the lives of the youth who live there. GridEd's impact is evident.

Georgia Tech developed a course curriculum for high school teachers to offer energy pathway lessons in the classroom and is summarized in Table 5 (next page). To broaden the impact, the curriculum was translated to Spanish. Related course materials such as presentations, activities, and problems have been disseminated to GridEd Affiliate universities via GridEd's SharePoint repository, and an outline is publicly available on the GridEd website. Clarkson University, among others, is using the material for K-12 activities in its geographical area.

Table 5 – Georgia Tech's Energy Pathway High School Curriculum

Unit	Lesson
Introduction to Energy	A History of Power Systems
	Energy
	Work
	Mechanical Power
	Power Generation
	The Utility Industry
	Introduction to Energy Sources
Non-Renewable Energy Sources	Petroleum
	Coal
	Natural Gas
	Nuclear
	Environmental Impact of Energy
	Case Study – Non-Renewable Energy Sources Overview
Renewable Energy Sources	Wind Power
	Solar Power
	Hydroelectricity
	Biofuel
	Other Renewables
	Case Study – Renewable Energy Sources Overview
Energy/Power Utilities in the United States Today	Overview of the Energy/Power Utility Industry Today
	Economics
	Economics of the Power Industry
	Regulations an Policies of the Utility Industry
	The Electric Grid and Power Quality
Energy and Power Utilities in the World	Energy Use in Other Nations
	Energy and Development
	Current Energy Status of Developing Nations
	Renewable Energy Trends in Developing Nations
Energy and Politics	Energy and US Politics
	Energy and International Politics
	A History of Energy and Politics
Energy Trends and Technology	Fracking, Tight Oil, and National Gas
	Microgrids and Smart Grids
	Electric Vehicles
	Energy Storage
	Grid Parity
	Effects of trends on utilities in the U.S.

Georgia Tech has also served on an advisory board with teachers and leaders from Atlanta Public Schools and Lockheed Martin to execute a STEM Certification program for 23 area middle and high schools. Helping teachers to incorporate energy education coursework into robotics and engineering programs is a key role for Georgia Tech students and faculty. They plan to beta test an "Electrical Energy, Current and Circuits" classroom lesson plan and lab curriculum with a group of Atlanta Public School student interns at Georgia Tech.

In a similar manner, UNCC annually participates in Discover Engineering Day, where hundreds of children age 10 through 16 attend day-long themed activities meant to raise STEM awareness. The Engineering college funded the purchase of activity kits for solar energy, fuel cell, and wind energy to highlight distributed energy resource technology for pre-college students. In addition, UNCC participated in Career Day at area elementary schools. UNCC also works to engage administrative personnel from the Charlotte Engineering Early College located on its campus. The intent is to introduce STEM certification based on Georgia Tech's successful outreach program.

UPRM's outreach has been structured around three main activities: 1) outreach to high school students and teachers, 2) public outreach to energy stakeholders in Puerto Rico, and 3) coordination of outreach seminars for adults as well as students held at communities in San Juan (El Caño Martín Peña) and southern Puerto Rico (El Coqui, Salinas). Instructional materials were developed for high school students and teachers including a hands-on experience in the energy conversion lab at UPRM. A series of intense seminars ("crash courses") on the existing electric power grid and the power grid of the future were delivered to professionals from the newly created Puerto Rico Energy Commission as well as citizen's advocacy groups ("Espacios Abiertos" and "Enlace" in San Juan). UPRM has also used these materials to present at other outreach events such as the Diáspora Summit, held in New York City where Puerto Rico's energy status and choices as well as a renewable energy roadmap were discussed. GridEd was presented as an important project for workforce development.

Clarkson's outreach activities have included a plan to integrate the Georgia Tech materials into area schools. Recently, the Clarkson investigators have been working with Clarkson's K-12 curriculum coordinator to develop material on energy, force and magnetism for 8th graders. Further, a complementary resilient microgrid project is underway, with significant community involvement. A National Science Foundation-funded multi-disciplinary

research project on this microgrid includes human factors, software, economics and political science experts in the GridEd outreach program.

NEGATIVE RESULTS AND/OR CHANGES TO ORIGINAL PROJECT PLAN

There were three aspects of this project which did not turn out as intended including 1) the delayed, but successful launch of a Professional Master's Degree Program at Georgia Tech which has not attracted anticipated corporate support to date, 2) the failure to enroll attendees into a series of professional training courses in year 1 of operation of GridEd, and 3) the struggle to create new student groups at each university for GEARED Student Innovation Board.

Professional Master's Degree Program

The Professional Master's Program did launch at Georgia Tech after some delays. The plan for the program was to engage corporate entities that would purchase access to the program and provide the students. However, to date only one corporate subscriber has participated -- Saudi Oil company. Future success of the program will be linked to securing corporate support.

The program is staffed with a list of experts in the various fields of the program including Electrical and Computer Engineering; Mechanical Engineering; and Industrial Systems and Engineering. There are six core courses (i.e., required): five in the first year and one capstone course in the second year. There are four elective courses (selected out of a pool of 10 courses) for the second year. The elective courses are selected and fixed per participant, and the choice is made based on the background of the students and their job descriptions.

Professional Training Course Series

In 2014, during GridEd's first year of operation, four short courses were marketed together as a "tutorial series" to address key aspects of distribution system design and operation that would prepare future utility staff for the integrated grid of the future. The courses being offered were:

- Distributed Storage and Generation Technologies & Applications
- Electric Power Distribution Systems
- Dynamic Distribution System Modeling
- Business Case Analysis in the electric utility industry.

These courses were offered in a sequence to allow a participant to build a knowledge tree with information and understanding to address the challenges of designing and operating the future grid. The courses were intended to address the fundamentals of future grid engineering by introducing critical technologies, familiarizing distribution grid design and operation, recognizing the dynamic characteristics of the distribution system of the future, and addressing the fundamentals of business case analysis needed to transition towards the future. The goal was that an individual could take the entire tutorial series will be able to provide expertise that spans several functional areas.

However, there was not a single person who signed up for all four courses. While this was the case, the principle of stringing together courses in key areas and perhaps providing some form of certificate may have value. Several aspects were working against the original GridEd effort. First, GridEd was in its first year of GridEd operation and GridEd did not have an established brand for T&E. Second, all courses were offered via live in-person mode of delivery which could make it difficult for an individual to travel to each location in the span of one year.

GEARED Student Innovation Boards

An innovative concept proposed by DOE to all GEARED consortia was to assemble student innovations boards (SIB) as described previously in this report. Initial efforts at universities attempted to create new GEARED student chapters or organizations and elect them to the overall GridEd SIB and then then roll those students into an overall GEARED SIB. However, logistical issues and capturing student interest in a "new" group made the effort unsuccessful. Eventually, the strategy shifted towards identifying student leaders of existing student organizations related to GEARED, and having a faculty identify the appropriate leader to serve on the SIB to meet together on collective calls to discuss ideas on how to best engage other students at respective campuses. This was a much more successful modeling of engaging students.

PUBLICATIONS, OUTREACH, AND OTHER OUTPUTS

The number of publications, outreach activities, and other outputs that the GridEd consortia has engaged with over the course of this project are too many to list in this report. Below is a summary of key engagements provided by the project team.

Publications

- *The Center for Grid Engineering Education (GridEd) 2014 Progress Report.* EPRI. Palo Alto, CA. 2017. 3002011182
- *The Center for Grid Engineering Education (GridEd) 2015 Progress Report.* EPRI. Palo Alto, CA. 2017. 3002011183
- *The Center for Grid Engineering Education (GridEd) 2016 Progress Report.* EPRI. Palo Alto, CA. 2017. 3002011184
- *The Center for Grid Engineering Education (GridEd) 2017 Progress Report.* EPRI. Palo Alto, CA. 2018. 3002012596
- *The Center for Grid Engineering Education (GridEd) 2018 Progress Report.* EPRI. Palo Alto, CA. 2019. 3002016652
- *Identifying Training and Education Gaps in the Electric Industry: A GridEd Report.* EPRI. Palo Alto, CA. 2018. 3002014732
- *Developing a Sustainable Business Model for Training and Education in the Electric Power: A GridEd Report.* EPRI. Palo Alto, CA. 2019. 3002014734
- *GridEd Human Resources Working Committee Report.* EPRI. Palo Alto, CA. 2019. 3002016750
- Stephen Bird, Amir Enayati, Chelsea Hotaling, and Tom Ortmeyer. "Resilient Community Microgrids: Governance and Operational Chllenges." In Energy Internet: An Open Energy Platform to Transform Legacy Power Systems into Open Innovation and Global Economic Engine, Alex Huang and Wencong Su, Ed. Elsevier, 2018. ISBN: 978-0081022078
- Yikui Liu, Jie Li, and, Lei Wu "Coordinated Optimal Network Reconfiguration and Voltage Regulator/DER Control for Unbalanced Distribution Systems." IEEE Transactions on Smart Grid early access 10.1109/TSG.2018.2815010.
- Dylan Dean, Thomas Ortmeyer, and Lei Wu. "Transportation Modeling and Data Needs for Fast Charging Electric Vehicles." 2016 IEEE Electrical Systems for Airraft, Railway, Ship Propulsion and Road Vehicles (ESARS)/International Transportation Electrification Conference (ITEC), November, 2016. doi: 10.1109/ESARS-ITEC.2016.7841384.
- Lei Wu, Tom Ortmeyer, Jie Li. "The community microgrid distribution system of the future." The Electricity Journal Volume 29, Issue 10, December 2016, Pages 16–21
- Wenbo Qi, Jie Li, Yaoqing Liu, and Chen Liu, "Planning of Distributed Internet Data Center Microgrids." IEEE Transactions on Smart Grid. Volume: 10 Issue: 1 pp. 762–771.
- B. Pejcinovic, R. Bass, and P. Wong, "Adapting scrum project management to ECE courses," in ASEE Annual Conference and Exposition (abstract accepted),Tampa, FL, June 15–19 2019.
- B. Pejcinovic, R. Bass, and P. Wong, "Assessing teamwork and scrum project management in ECE courses," in ASEE Annual Conference and Exposition, Salt Lake City, UT, June 24–27 2018.
- B. Pejcinovic, P. Wong, and R. Bass, "Preparing freshman ECE students for project management," in ASEE Zone IV Conference (poster presentation), Boulder, CO, March 25–27 2018.
- B. Pejcinovic, J. Grant, and R. Bass, "Applying scrum project management in ECE curriculum," in Frontiers in Education 2016, Erie, PA, October 12–15 2016.
- Peng, Chaoyi, Yunhe Hou, Nanpeng Yu, and Weisheng Wang. "Risk-limiting unit commitment in smart grid with intelligent periphery." IEEE Transactions on Power Systems 32, no. 6 (2017): 4696–4707.
- Shi, Jie, Nanpeng Yu, and Weixin Yao. "Energy efficient building HVAC control algorithm with real-time occupancy prediction." Energy Procedia 111 (2017): 267–276.
- Wang, Wei, and Nanpeng Yu. "Phase Balancing in Power Distribution Network with Data Center." ACM SIGMETRICS Performance Evaluation Review 45, no. 2 (2017): 64–69.
- Liu, Yang, Nanpeng Yu, Jie Shi, Bing Dong, Wei Ren, and Xiaohong Guan. "Evaluation of frequency regulation provision by commercial building HVAC systems." In 2017 13th IEEE Conference on Automation Science and Engineering (CASE), pp. 888–893. IEEE, 2017.

- I. N. Moghaddam, B. H. Chowdhury, M. Doostan, "Optimal Sizing and Operation of Battery Energy Storage Systems connected to Wind Farms Participating in Electricity Markets," IEEE Transactions on Sustainable Energy, early access, https://ieeexplore.ieee.org/document/8425780 [ieeexplore.ieee.org]
- N. Kim, B. Parkhideh, "Control and Operating Range Analysis of an AC-Stacked PV Inverter Architecture Integrated with a Battery," IEEE Transactions on Power Electronics, Volume: 33 , Issue: 12, Apr. 2018, pp. 10032 - 10037, https://ieeexplore.ieee.org/document/8345655 [ieeexplore.ieee.org]
- M. Biglarbegian, I. Mazhari, H. Jafarian, N. Kim, B. Parkhideh, J. Enslin, "Multi-purpose generic board for hands-on power electronics education of different power converter topologies in PV applications," 2018 IEEE Applied Power Electronics Conference and Exposition (APEC), pp. 1147–1154, San Antonio, TX, March 4–8, 2018
- T. Slay, "Dispatching Residential Assets for Utility Ancillary Services." DistribuTech Conference & Exhibition, New Orleans, LA, February 5, 2019.
- J. Kolln, "Finite element analysis of transformers in subterranean vaults" (best student poster award). IEEE PES General Meeting, Portland, OR, August 5–10 2018.
- T. Slay, "Adoption of IoT framework for DER aggregation and control."
- K. Marnell and M. Obi, "A distributed energy resource aggregation system for providing ancillary services." IEEE PES General Meeting, Portland, OR, August 5–10 2018.
- C. Eppinger, "Content development of IoT for grid modernization – a two-class series for the future power engineer." IEEE PES General Meeting, Portland, OR, August 5–10 2018.
- C. Eppinger, "Analysis of Conservation Voltage Reduction by Var Injection of a Utility, Distribution Feeder in OpenDSS." DistribuTech Conference & Exhibition, Dan Diego, CA, January 31, 2017.
- T. Slay, "Utility Owned Residential Battery Energy Storage Systems for Ancillary Services." DistribuTech Conference & Exhibition, Dan Diego, CA, January 31, 2017.
- Clarke, "Using the Alljoyn Framework for Smart Grid Applications." DistribuTech Conference & Exhibition, Dan Diego, CA, January 31, 2017:
- Clarke, M. Davis, "Water Heater Controls: Emulator Models, Testing & Validation, and Support Vector Machines." OR BEST, Portland, OR, 2017.

Further, material developed at ASU on the dynamic modeling of renewable resources including both wind turbine generators and photovoltaic resources have been included in the 3rd Edition of the book Power System Control and Stability, Vijay Vittal and James McCalley, previously written by P.M. Anderson and A.A. Fouad, Wiley Interscience and IEEE Press, to be published in August 2019. An acknowledgement of the project support is included in the preface of the book.

There were student activities, research projects, papers, and presentations at conferences that were supported by the project but were not mentioned due to length. Some highlights include IEEE student banch chapter members organizing and offering seminars for other engineering students on multiple topics including: LeTeX, Scrum project management, modeling with OpenDSS, and other DistribuTECH research topics. Students also organized tours of regional companies and facilities such as the BPA Control Center, PSU's subterranean power system, Lewis PUD, PGE Sullivan generation station, and local electric storage system manufacturing plants.

UPRM also supported a Microgrid Laboratory. The facility allows UPRM to have experimental demonstrations, and tutorials, as well as short and long practical courses attractive to both academia and industry. It supports five courses and several research projects, serving about 100 students per year. In addition, UPRM also held two local colloquia on the topic to solar communities in the city of Ponce and Bayamón in Puerto Rico to 150 community leaders.

JOB CREATION AND ECONOMIC STIMULUS ACTIVITIES

GridEd has had a direct impact on preparing the future electric grid workforce to become competent electric power engineers that have full knowledge of integrating renewable energy resources. Two specific activities related to the educational stimulus provided by GridEd are summarized on the following page.

Student Employment Surveys

In collaboration with the GEARED National Network Administrator, GridEd participated in a student employment survey to track the employment status of undergraduate and graduate students in the GEARED university network. The survey was administered to students at GEARED universities who were taking in at least one course indicative of someone who might focus on power engineering across all of the universities in the GEARED network. Results from the survey revealed that 75% of students indicated that they wanted to work in the electric power industry after graduation and 38% of students plan to work at a utility company after graduation.

Select reasons students say "YES" to the Electric Power Industry

- The Electric Power industry will continue to grow as it innovates and updates the existing power grid.
- It seems to be a prestigious and useful field of work
- Viewed as a very diverse field with much new technology being prevalent in the near future or at least within the span of a professional career
- Yes, e.g., one student said because I have interned for over 3 years as an engineering intern and for 3 power related companies – I have loved everything I have done and learned.

Select reasons student say "NO" to the Electric Power Industry

- Electrical & Computer Engineering (ECE) classes have taught me that I am not prepared enough to work with electric power. The math concepts, although easy for most, are really difficult for me
- I am more interested in other topic areas
- The electric power industry has a lot of bureaucracy
- Electric Power isn't as interesting as other fields (embedded systems)
- I am more interested in working at an aerospace company in a Mechanical engineering technology job

Extension of the Basic Power Course

These materials are publicly available and have been adopted as a basis by the Center for Advanced Power Engineering Research (CAPER) organization, presently based in Charlotte, North Carolina, to deliver a compact, basic power systems course in a live in-person two-week format with self-study using many of the recorded lectures. The CAPER course was launched in May 2019 and is a great example of how materials under the GridEd program can be sustained.

PROJECT SPENDING

Geared (DE-EE0006338)

Spending for this project met budgeted expectations. Total project spending was mostly on track but slightly higher than with the original planned budget. This extra spending on labor, travel, and meeting expenses was expected due to the higher demand in professional training courses. Given the sustainable model setup as part of the project goals, the revenue generated from these additional courses helped provide more cost share than what was in the original project plan.

Step (DE-EE0007328)

Similar to the GEARED award, the total project spending for the STEP award was on track with expectations from the original plan. Though spending was slightly higher for personnel, this was expected given additional effort spent on short courses and sustainability due to the higher demand than what was originally anticipated. Similar to the GEARED award, the extra effort in short courses and sustainability resulted in higher cost share for the project than what was called for in the original plan.

PATH FORWARD

From the beginning of the GridEd project, the team has focused on creating a sustainability plan for GridEd or a GridEd-like entity supported and financed through EPRI in a post-DOE-funded era. To achieve that goal, positive business cases have been identified where participants obtain value for T&E products and services. The GridEd team envisions sustaining a T&E activity through EPRI's collaborative business model whereby high-value propositions related to T&E can be financially supported. In particular, several key elements that provide long-term stability are centered around GridEd's management by EPRI and EPRI's mission of addressing the challenges in the electricity industry. These include:

- EPRI's collaborative strength to build strong ties between utilities and universities;
- EPRI providing ongoing access to Short Course programs for the electric industry;

- EPRI actively expanding relationships with universities;
- EPRI seeking electric industry executive commitment to the value of T&E for its professional staff;
- EPRI seeking out and using modern technology to more easily access the industry as a whole.

EPRI has expanded its role in T&E through the launch of EPRI U and supporting infrastructure to host computer-based training modules. This is a significant step forward in T&E considering historically EPRI has focused on the R&D aspects and left most training to other entities except in unique circumstances.

Building off the original 5-year GridEd effort, EPRI along with electric utility partners and universities have been selected by the U.S. Department of Energy Solar Energy Technologies Office (SETO) to receive a $6.55 million award to launch the Grid-Ready Energy Analytics Training (GREAT) with Data initiative (award DE-EE0008574). The project will design, develop and deliver professional training materials to train and recruit power systems workers and university curricula for new engineers and computer scientists. It will also develop certifications, credentials, qualifications, and standards for the T&E needed in the electric utility industry workplace to transform the grid. The GREAT with Data initiative will help merge Grid Operations Technology and Information Technology to enable the integration of distributed energy resources (DER), especially solar, through enhanced industry coordination and workforce readiness initiatives by training, educating, and recruiting qualified personnel into the electric utility industry.

The creative commons content developed through the project will address workforce skills in four key technical areas:

- Data science, including descriptive, prescriptive, and predictive analytics, and machine learning;
- Cyber security;
- Information and communication technologies including increased grid interoperability and standardization; and
- Integration of solar photovoltaic and other synergistic DER such as energy storage, electric vehicles, demand response, etc.

The GREAT with Data initiative will allow EPRI to expand the technical content offerings of GridEd beyond the other sustaining aspects of the initial 5-year effort. To continue the sustaining aspects of GridEd, EPRI has created new projects to facilitate utility access to T&E opportunities. Our goal is to build upon the utilities that are part of GridEd and to broaden access to the industry.

ACKNOWLEDGEMENT

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DISCLAIMER

Appendix A: Milestone Table for DE-EE0006338

Table 6 – Caption Needed

Budget Period	Quarter	Milestone or Go/No-Go ID	GridEd - Milestone or Go/No-Go Description	Verification Mechanism and/or Deliverable	Relevant Task(s) and Subtask(s)
2	5	M4.2.1	Continuously review and evaluate and gather feedback on short-courses/webinars content and offerings.	4.2 Document number of evaluations received per event	4.2
		M6.1.1	Promote the GEARED activity and use the GEARED and GridEd logos where applicable	6.1 Logos used on appropriate delivered material	6.1
		M8.2.1	Post up to date information regarding course offerings, workshops, events, conferences, student information and other related resources and information to the GridEd website.	8.2 Updated website	8.2
		M8.3.1	Participate in monthly teleconferences with all GEARED consortia members, facilitated by the GEARED NNA.	8.3 Participation in monthly calls	8.3
		M11.1	Evaluate and restructure staff as needed to successfully manage the project.	11.1 Document staff restructuring as needed	11.1
		M11.2.1	Hold regular coordination meetings and workshops among GridEd universities and utility advisors	11.2 Conference call	11.2
		M11.3.1	Complete reporting as required by GEARED NNA and US DOE	11.3 Reporting completed	11.3
2	6	M1.1.1	Establish quantitative metrics for the number of topics, courses, credit hours and/or students we will engage, in consultation with all project partners.	1.1 Document metrics to be tracked	1.1
		M1.2.1	Establish a Strategic Dissemination and Evaluation Plan for ongoing feedback on performance.	1.2 Strategic plan document	1.2
2	6	M2.2.1	Arrange a workshop to review utility needs and knowledge gaps.	2.2 Workshop agenda and meeting notes	2.2
		M3.4.1	Design and develop curriculum and course materials for professional masters program in power system engineering with topics on distributed generation	3.4 Degree program listed through university	3.4
		M4.2.1	(ongoing)		
		M6.1.1	(ongoing)		
		M8.1.2	Review and update EPRI web site structure and revise as necessary the dissemination protocol for materials (research, course descriptions{as detailed by the GEC}, and GEARED student events, internships and coop positions), news and shared learnings as necessary	8.1.2 Website updated	8.2
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.1.1	Create criteria for the selection of students to a GridEd Student Innovation Board.	9.1.1 Document criteria	9.1
		M9.1.2	EPRI will select and publicize a full roster of the GridEd SIB members for the 2014-15 academic year.	9.1.2 Roster posted on website	9.1
		M10.1.2	In coordination with the GEC, GridEd will establish a schedule for its own regional Student-Centered Conference.	10.1.2 Document GridEd Conference Plan	10.1
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
BP 3->		**BP3 GNG**			
3	7	M1.4.2	Revise as necessary the Strategic Dissemination and Evaluation Plan based on feedback.	1.4.2 Revised plan document	1.4
		M4.2.1	(ongoing)		
		M4.3.1	Per utility requirement (see 2.2), repeat the offering of select short courses/webinars with updated content based on evaluations (see 4.2)	4.3 Repeat course delivery as necessary	4.3

Table 6 – Caption Needed (continued)

Budget Period	Quarter	Milestone or Go/No-Go ID	GridEd - Milestone or Go/No-Go Description	Verification Mechanism and/or Deliverable	Relevant Task(s) and Subtask(s)
3	7	M6.1.1	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	Maintain support with faculty sponsorship, engagement, and a dedicated allocation of student-controlled funding for university chapters of GEARED scholars on each EPRI university member campus. Post GridEd scholar activities on GridEd website.	9.3 Document student support at each Partner university	9.3
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
3	8	M1.3.1	Establish a dissemination mechanism for materials, news and shared learning, and a communication plan for the network, and between the network and the GEARED National Network Administrator (NNA).		
		M3.2.1	Each Partner university to offer at least one undergraduate, graduate, or continuation education course in power engineering with revised curriculum.		
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M5.1.1	Identify e-learning module topics and open-access platform to host them.		
		M6.1.1	(ongoing)		
		M6.3.1	Develop strategic plan to increase utility participation in the GridEd DTTC; document the mechanism for utilities currently outside the GridEd DTTC to join the collaborative	6.3 Document mechanism to join	
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.2.1	Establish a GEARED student scholar link to an existing student organization (or promote the creation of a new student organization where applicable) related to power engineering for GEARED scholars at each GridEd Partner and Affiliate university.	9.2 Document connection at each university	9.2
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
3	9	M4.1.1	GridEd will deliver at least four new (in addition to those delivered in BP1) short courses/webinars on selected topics to address gaps identified by utilities	4.1 Course delivery complete	4.1
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.4.1	Assist GridEd SIB representatives and GEARED scholars to participate in the annual GEARED Student-Centered Research Conference (NAPS 2015 at UNC)	9.4 GridEd student attendance at NAPS	9.4
		M9.3.1	(ongoing)		
		M10.4.1	Establish working committees to plan and support all facets of GEARED Student-Centered Research Conferences	10.4 Contact list of working committees	10.4
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		

Table 6 – Caption Needed (continued)

Budget Period	Quarter	Milestone or Go/No-Go ID	GridEd - Milestone or Go/No-Go Description	Verification Mechanism and/or Deliverable	Relevant Task(s) and Subtask(s)
3	10	M1.4.1	Evaluate project according to established metrics, evaluation mechanisms, and feedback from partners and DOE.	1.4.1 Evaluation Report	1.4
		M2.2.1	(ongoing)		
		M2.2.2	Review and revise utility power system engineering gap analysis mitigation plan	2.2.2 Revised document	2.2
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M8.1.2	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		M10.2.1	GridEd will encourage its university and student members to participate in other DTTC student-centered conferences.	10.2 Communication sent to students via email, flier, and/or other media	10.2
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
BP 4->		BP4 GNG			
4	11	M1.4.2	(ongoing)		
		M3.3.1	Each Partner university will offer at least one additional (to BP 3) new undergraduate, graduate, or continuing education power engineering course with advanced RE-related curriculum.	3.3 Courses listed through universities	3.3
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M4.4.1	Develop and deliver two additional short-courses and webinars on critical topics per utility requirements (see 2.2).	4.4.1 Course delivery complete	4.4
		M6.1.1	(ongoing)		
		M6.4.1	Develop and implement a strategic plan to increase paid participation from institution outside the collaborative in short courses and other commercial professional development offerings.	6.4 Document plan	6.4
		M7.1.1	Offer outreach materials in a least 4 events (one local to each Partnering university)	7.1.1 Four (4) events completed	7.1
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
4	12	M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M5.3.1	Add at least two e-learning modules into the open-access platform.	5.3.1 Two modules uploaded to platform	5.3
		M6.1.1	(ongoing)		
		M7.3.1	Disseminate best practices and lessons learned from short course offerings, university curriculum, e-learning, and K-12 outreach activities to other GEARED stakeholders via a workshop or webcast.	7.3 Workshop or webcast	7.3

Table 6 – Caption Needed (continued)

Budget Period	Quarter	Milestone or Go/No-Go ID	GridEd - Milestone or Go/No-Go Description	Verification Mechanism and/or Deliverable	Relevant Task(s) and Subtask(s)
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
4	13	M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
4	14	M1.4.1	(ongoing)		
		M.2.2.1	(ongoing)		
		M.2.2.2	(ongoing)		
		M3.5.1	GridEd partners will explore additional educational delivery models and distance learning formats (webinar, live-online, computer based training, etc.)	3.5 Draft plan to incorporate alternative delivery methods	3.5
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M6.2.1	Establish at least two marketing and outreach platforms for advertising of the DTTC academic and professional development course offerings		
		M7.2.1	Offer at least 1 workshop to train at least 25 instructors from non-Partner universities and utilities on selected short course and undergraduate/graduate course topics.		
		M8.1.2	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		M9.4.1	Assist EPRI SIB representatives and GEARED Scholar chapter members to participate in the annual GEARED Student-Centered Research Conference (location TBD)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
BP 5->		**BP5 GNG**			
5	15	M1.4.2	(ongoing)		
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		

Table 6 – Caption Needed (continued)

Budget Period	Quarter	Milestone or Go/No-Go ID	GridEd - Milestone or Go/No-Go Description	Verification Mechanism and/or Deliverable	Relevant Task(s) and Subtask(s)
5	15	M4.4.2	Develop and deliver two additional short-courses and webinars on critical topics per utility requirements (see 2.2).	4.4.2 Course delivery complete	4.4
		M6.1.1	(ongoing)		
		M7.1.2	Refine outreach materials and offer at least 2 more outreach events (in addition to those offered in BP4)	7.1.2 Two (2) events complete	7.1
		M7.1.3	Broadly disseminate outreach materials for middle/high school students through cross-posting to the GridEd and NNA web sites.	7.1.3 Links posted on website	7.1
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
5	16	M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M5.3.2	Add at least two more e-learning modules in addition to those already available into the open-access platform.	5.3.2 two modules uploaded to platform	5.3
		M6.1.1	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		M10.1.2	GridEd will host an annual regional Student-Centered Research Conference.	10.1.2 Conference completed	10.1
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
5	17	M2.2.3	Generate and disseminate a summary report of professional skills gaps and the efficacy of mitigation activities to address those gaps	2.2.3 Summary report	2.2
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
5	18	M2.2.1	(ongoing)		
		M2.2.2	(ongoing)		
		M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M4.5.1	Compile all new course curricula (detailed topical agendas) developed through the GEARED award centrally; make the curricula publicly available.	4.5 Course curricula disseminated and made publicly available	4.5
		M5.1.2	Make all e-learning modules available to the GEARED network through cross-posting to the GridEd and NNA web sites.	5.1.2 Links posted to GridEd website	5.1

Table 6 – Caption Needed (continued)

Budget Period	Quarter	Milestone or Go/No-Go ID	GridEd - Milestone or Go/No-Go Description	Verification Mechanism and/or Deliverable	Relevant Task(s) and Subtask(s)
5	18	M6.1.1	(ongoing)		
		M6.5.1	Test and evaluate the capacity of the GridEd course offerings to be self-sustaining through fee-based, subscription or other means of payment for the GEARED-developed professional course offerings generated from GridEd stakeholders.	6.5 Evaluation of fee based offerings	6.5
		M8.1.2	(ongoing)		
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		M9.4.1	(ongoing)		
		M10.3.1	Assist EPRI SIB representatives and GEARED scholars to participate in a national GEARED Student-Centered Research Conference (location TBD)	10.3 Student attendance at conference	10.3
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
5	19	M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M7.4.1	A report summarizing best practices in human resources including topics such as recruiting, retention, and outreach for underrepresented audiences which include minorities, women, and veterans.	7.4.1 Report disseminated to GEARED stakeholders	7.4
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		
5	20	M4.2.1	(ongoing)		
		M4.3.1	(ongoing)		
		M6.1.1	(ongoing)		
		M7.2.2	Offer at least 1 more workshop (in addition to the workshop in BP4) to train at least 25 instructors from non-Partner universities and utilities on selected short course and undergraduate/graduate course topics.	7.2.2 Workshop complete	7.2
		M8.2.1	(ongoing)		
		M8.3.1	(ongoing)		
		M9.3.1	(ongoing)		
		11.1.1	(ongoing)		
		11.2.1	(ongoing)		
		11.3.1	(ongoing)		

Appendix B: Milestone Table for DE-EE0007328

Table 7 – Caption Needed

Milestone Summary Table						
Recipient Name / Project Title:			Electric Power Research Institute (GridEd-West) / Leveraging Industry Research to Educate a Future Electric Grid Workforce			
Task	Task/Sub-Task Title	Milestone Type	Milestone Number	Milestone Description	Milestone Verification	Quarter
1	Eval. Plan	Milestone	M1.1	Establish quantitative metrics (# of topics, courses, students, etc).	Metrics Document	Q1
1	Eval. Plan	Milestone	M1.2	Update GridEd strategic plan based on GridEd-West objectives.	Updated Document	Q2
1	Eval. Plan	Milestone	M1.3	Evaluate project according to network-developed metrics	Eval. Document	Q8
2	Utility Gaps	Milestone	M2.1	Establish an advisory committee incorporating subject matter experts.	List of Contacts	Q3
2	Utility Gaps	Milestone	M2.2.1	Arrange at least one workshop per budget period to review utility needs.	Workshop	Q3, 7, 11
2	Utility Gaps	Milestone	M2.2.2	Disseminate a summary report of professional skills gaps.	Report	Q4, Q10
2	Utility Gaps	Milestone	M2.3.1	Implement outreach campaign promoting GEARED student employment	Document/Web Posts	Q4
2	Utility Gaps	Milestone	M2.3.2	Revise outreach campaign promoting GEARED student employment	Document/Web Posts	Q8
3	Curriculum	Go/No-Go	M3.1	Develop at least 2 REVISED and 2 NEW undergraduate or graduate power engineering courses.	Course Syllabi	Q4
3	Curriculum	Go/No-Go	M3.2	Offer at least 2 NEW and 2 REVISED undergraduate or graduate power engineering courses.	Course Listing	Q8
3	Curriculum	Milestone	M3.3	Offer at least 2 add'l REVISED and 2 add'l NEW courses.	Course Listing	Q11
4	Short Courses	Go/No Go	M4.1.1	Deliver at least one short course/webinar on selected topics.	Course Registration	Q4
4	Short Courses	Go/No Go	M4.1.2	Deliver at least 1 additional short course/webinar on selected topics.	Course Registration	Q8
4	Short Courses	Go/No Go	M4.1.3	Deliver at least 1 additional short course/webinar on selected topics.	Course Registration	Q12
4	Short Courses	Milestone	M4.2	Avail all topical agenda for developed short courses	Website Posting	Q12
5	Sustainability	Milestone	M5.1	Use GEARED and GridEd logos as appropriate	Logos on Materials	All
5	Sustainability	Milestone	M5.2	Advertise GridEd-West professional course offerings	Adds Distributed	Q6
5	Sustainability	Milestone	M5.3	Collaborate with universities for fee-based courses	Univ. Course (Fee)	Q12
6	Tech Transfer	Milestone	M6.1	Conduct workshop to train at least 15-20 trainers from other institutions	Workshop	Q11
7	Website/Com	Milestone	M7.1	Expand GridEd website to include GridEd-West stakeholders	Website updated	Q2
7	Website/Com	Milestone	M7.2	Regular communication including monthly teleconference web posts	Calls & Web Posts	All
8	Students(SIB)	Go/No-Go	M8.1	Establish GridEd-West SIB among Partnering universities	Contact Info	Q3
8	Students(SIB)	Milestone	M8.2	Link SIB to existing organizations on respective campuses	Document	Q6
8	Students(SIB)	Milestone	M8.3	Maintain faculty support and sponsorship through funding	Document	All
9	Management	Milestone	M9.1	Establish GridEd-West among Partnering institutions	Contracts Signed	Q1
9	Management	Milestone	M9.2	Complete reporting requirements required by the NNA and DOE	Reports Uploaded	All

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3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 • USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com