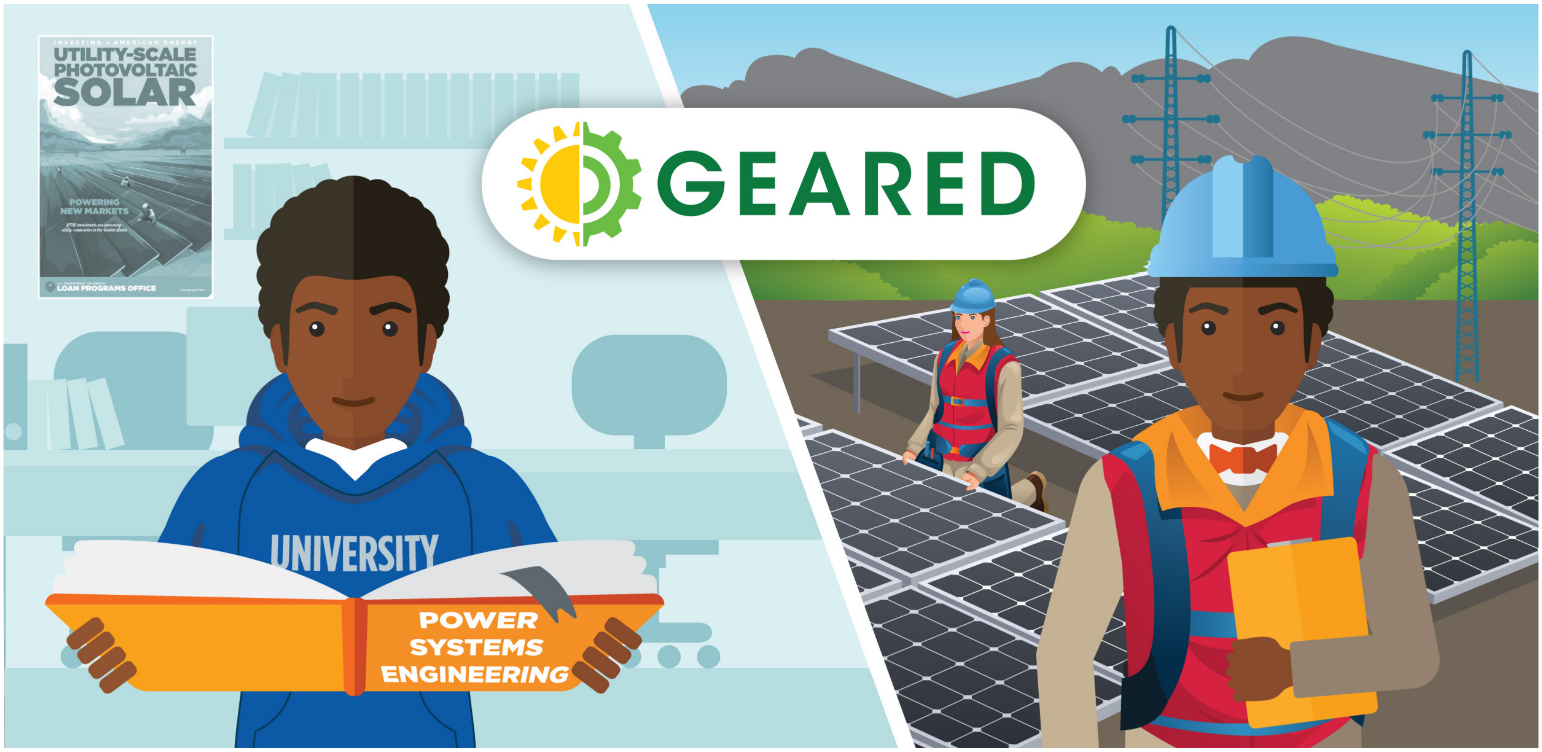
SunShot U.S. Department of Energy

THE SUNSHOT INITIATIVE




# GEARED Peer Review Report

January 2017

## Executive Summary

Throughout the dramatic changes that the electric industry has undergone in the last three decades, two fundamental features underpin the challenges of integrating distributed renewable energy: (1) historically electricity only flowed in one direction and (2) it was not stored in any significant quantity. Significant and broad technology advancement, engagement with more and diverse stakeholders, and new skills and training will be needed as the grid necessarily evolves. Gaps exist throughout the industry and many challenges for high renewable energy penetration are already present. The promise of GEARED is to mobilize university and industry to address the skills and training gap related to the grid of the future, including incorporation of renewable energy resources, and address the need to hire and train a workforce to replace retiring utility personnel. Cost effective grid modernization requires expanding power systems skillsets to include communications, controls, and broader business and society engagement. The GEARED Network is well timed and placed to address these challenges. The following are highlights of their value and performance:

- Successful curriculum development
  - New and revised courses better address high renewable energy penetration
  - All Distributed Technology Training Centers (DTTCs) have had some successes at course sharing among universities within individual consortia
  - Short courses address material that is important to current professionals
- Close alignment of industry and GEARED priorities
  - Student design projects are highly relevant to the power systems industry
  - Industry perceives GEARED students as better prepared for power systems engineering jobs than non-GEARED students
- High student engagement
  - The GEARED program bolsters undergraduate and graduate attendance at relevant conferences, fostering industry collaborations
  - Student participation in Student Innovation Boards (SIBs) fosters leadership skills and builds connections to industry

For the remaining two years of the GEARED program, challenges (and therefore innovation opportunities) remain. There is a need to:

- Implement innovative teaching practices and expand grid modernization curriculum
- Expand the pipeline of power systems professionals
  - Leverage existing projects for outreach to high school students and rising freshmen.
  - Increase workforce diversity (e.g., targeting veterans, women, and minorities).
- Evaluate GEARED’s impact with respect to ultimate program goals (e.g. employment of students/trainees facilitated by GEARED)

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# 1 GEARED Background

Through the U.S. Department of Energy (DOE)'s SunShot Initiative, the Grid Engineering for Accelerated Renewable Energy Deployment (GEARED), program was created to build a training and education framework that grows the expertise and preparedness of current and future electric utility sector professionals – specifically to accommodate high penetrations of solar electricity and other distributed technologies.

The impetus for the GEARED project comes from several challenges: an aging utility workforce, the large number of imminent retirements in U.S. plants, and the need to significantly upgrade the curriculum of power systems engineering programs to address projected needs.

Equally important, the GEARED program fills an urgent need for increased power system research, development and analytical capacity, and for integrating these findings into education and training.

The goal is to create a national network of centers that support power systems training and curriculum development based on research, development, data generation, collection, analysis and simulation.

Central to the five-year GEARED project is the Distributed Technology Training Consortia (DTTC). Composed of three regional consortiums, each with multiple university, utility and industry partners, the collaborators are working toward the infusion of power systems analysis and research and development (R&D) into training activities such as curriculum and short course development, internships and co-ops, and continuing education. In addition, each DTTC has a Student Innovation Board (SIB), which is a student-run organization that promotes leadership and organizes networking opportunities between students and industry.

The Interstate Renewable Energy Council (IREC) serves as the National Network Administrator (NNA) of GEARED, coordinating activities among the consortia included in the GEARED Network and ensuring that the consortia's efforts are cohesive across the country. The consortia are Mid-America Regional Microgrid Education and Training (MARMET), led by the Missouri Institute of Science and Technology; Foundations for Engineering Education in Distributed Energy Resources (FEEDER), led by the University of Central Florida; and The Center for Grid Engineering Education (GridEd), led by the Electric Power Research Institute (EPRI).

GEARED creates a network of professionals that develop and widely disseminate content and curriculum for training and education programs that focus on system implications of distributed power technologies. Via this network, the DTTCs identify and share training and education best practices and programs, as well as power system research and development.

# 2 Peer Review Process

An in-person peer review meeting was held in October 2016. Reviewers included Parhum Delgoshaei (Penn State University), Jenefer Husman (University of Oregon), Jeremiah Miller (U.S. Department of Energy), Dana Olson (U.S. Department of Energy), and Anil Pahwa (Kansas State University). Representatives from each awardee team were also in attendance. The full list of attendees is included in the Appendix.

Each awardee presented a high-level review of how their program achieved the three topics listed in the agenda, which included (1) University Curriculum Development, Student Engagement Efforts, and Professional Skills Courses, (2) Utility and Industry Engagement Efforts, and (3) GEARED Structure Administration, and Evaluation. Reviewers also met independently with utility and industry stakeholders via telecom. Reviewers interacted with students during R&D and design project presentations as well as during a closed session with SIB leadership via telecom. Reviewers performed SWOT (Strengths, Weaknesses, Opportunities, Threats) analyses and asked follow-up questions of the awardees that the project teams answered on the second day.

Finally, reviewers wrote 12 reports including:

(1) Overall Value and Performance of the GEARED Network,

(2) List of Significant Achievements,

(3) Curriculum Development,

(4) Curriculum Sharing and Network Design,

(5) Industry Employment Needs,

(6) Industry Engagement in Projects,

(7) Student Employment Preparedness,

(8) Student Innovation Boards and Other Student Activities,

(9) DTTC Design and Cohesiveness,

(10) GEARED Administration,

(11) GEARED Internal Evaluation Efforts, and

(12) Involvement in GEARED Outreach and Education.

Reviewers also scored each awardee based on **(1)** Market Transformation, **(2)** DTTC/Network Administration, **(3)** Productivity and Relevance, and **(4)** Innovation. The commentary in this report is based on reviewer reports and scoring justification.

# 3 Overall GEARED Performance and Future Directions

Throughout the dramatic changes that the electric industry has undergone in the last three decades, two fundamental features underpin the challenges of integrating distributed renewable energy: (1) historically electricity only flowed in one direction and (2) it was not stored in any significant quantity.[1] Significant and broad technology advancement, engagement with more and diverse stakeholders, and new skills and training will be needed as the grid necessarily evolves. The promise of GEARED is to:

(1) Mobilize university and industry to address the skills and training gap related to the grid of the future, including incorporation of renewable energy resources, and

(2) Address the need to hire and train a workforce to replace retiring utility personnel.

The following subsections address curriculum development, industry engagement, student engagement, and evaluation in more detail.

## 3.1 Curriculum Development & Sharing

Development and sharing of curriculum material is the centerpiece of the work of the DTTCs. A list of new and revised courses generated from GEARED is listed in the Appendix. All programs have addressed the need for including power systems courses or course sections focusing on intermittency and integration issues associated with renewables. In addition, dedicated courses for economic and market aspects of energy generation including distributed energy resources have been developed. However, there has been less emphasis on implementing innovative teaching practices (e.g. experiential learning) and promoting curriculum sharing. In addition, it would be valuable to extend the market value for the GEARED curriculum. For example, this could include a certificate of completion, LinkedIn badge, or grid modernization "certification".

1 Kristov, Lorenzo and Paul De Martini (2014). *21st Century Electric Distribution System Operations*. http://gridarchitecture.pnnl.gov/media/white-papers/21st%20C%20Electric%20System%20Operations%20%20050714.pdf

Although there has been a lot of progress in curriculum development, there are still topics related to high renewable energy penetration that are not well addressed. The curriculum needs to provide students with the necessary tools to meet the challenges of the future grid. For example, GEARED is well placed to engage members and collaborate on smart grid courses and curriculum. Courses could address the fact that the current definition of grid hosting capacity is not in line with high penetration goals. The two most prominent definitions are in Table 1. These definitions align with a static snapshot of grid capacity that is based on worst case planning and assumes little to no operational changes (i.e., the utility applies a "fit & forget" approach to interconnect distributed energy resources (DER)). High penetration of renewable energy on the grid will be cost prohibitive through traditional transmission and distribution reinforcements and at current energy storage costs, thus smart grid techniques will play an active role in grid integration challenges.

Table 1. Definitions of grid hosting capacity.

| Definition 1 | Definition 2 |
|---|---|
| "The concept of hosting capacity is used to study how much PV can be placed on a feeder before negative effects on normal distribution system operation and power quality occur. Hosting capacity is typically expressed as the megawatt value of PV spread across any locations on the feeder that causes the first violation of operating constraints."[1] | "Hosting capacity is defined as the amount of DER that can be accommodated without adversely impacting power quality or reliability under existing control configurations and without requiring infrastructure upgrades."[2] |

Other topics that support faster interconnection approval and cheaper interconnection of distributed resources (especially for sites with prohibitively high grid integration costs) and thus would be good topics of curriculum developed by the GEARED DTTCs include:

- Addressing high penetration challenges for large commercial/utility/community solar arrays. Here, single individual large arrays (e.g. 2MW community solar area on a suburban/rural feeder) can trigger high penetration barriers
- Standardizing and streamlining interconnection and municipal permitting (e.g. construction/fire department/etc.)
- Gathering/creating/cleansing/verifying distribution circuit data and models, including Monte Carlo techniques to build models from generic load & generation profiles and other techniques when historical data is missing
- Automating interconnection technical screen analysis and fast-track preliminary approval for qualified projects
- Creating capacity headroom maps (e.g. similar to California 'heat maps' for low/medium/high estimated integration potential color classifications)
- Identifying innovative approaches to address today's grid integration challenges, such as alternatives to Direct Transfer Trip (DTT), alternatives or lower cost options for neutral overvoltage protection (3V0 relaying), applications of smart inverter functionality, methods to mitigate overvoltage, distributed/grid-edge monitoring &

2 Palmintier, Bryan, Robert Broderick, Barry Mather, Michael Coddington, Kyri Baker, Fei Ding, Matthew Reno, Matthew Lave, and Ashwini Bharatkumar. (2016). On the Path to SunShot: Emerging Issues and Challenges in Integrating Solar with the Distribution System. (pg. 20). Golden, CO: National Renewable Energy Laboratory. NREL/TP-5D00-65331. http://www.nrel.gov/docs/fy16osti/65331.pdf

3 EPRI (2016). Defining a Roadmap for Successful Implementation of a Hosting Capacity Method for New York State. (pg 2). http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002008848

control, etc.[4]

- Achieving high DER and bi-directional power flow on distribution grids without pervasive communications/sensors
- Increasing grid hosting capacity beyond the static snapshot/worst case/fit & forget paradigms that dominate DER interconnection paradigms today
- Synchronizing gaps in standards with industry needs/proactive changes (e.g. Rule 21/More than Smart/NY REV/OpenFMB)
- Addressing utility business models and emerging priorities for Distribution System Operators (DSOs).
- Engaging on smart grid techniques for addressing high renewable energy deployment that aims to specifically go above worst case planning/operations scenarios (i.e. FERC SGIP; above minimum load; above peak load; etc.).

In addition, there is an assumption embedded within the GEARED program that students will be change agents. However, effective change agents will likely need mentoring and training in behavior sciences in order to truly cause change within their organizations. In this same vein of thought, greater engagement of existing industry professionals (e.g. through expanded mid-career training opportunities) would serve to encourage change and innovation at higher, more established levels of organizations than can be achieved in the short-term through students that are brought in as new hires.

Course revising, such as that done by GEARED DTTCs, also provides an opportunity to maximize innovations in instructional design. MARMET's emphasis on experiential education is laudable, however, an overall strategy to move away from standard teaching practices to more engaging teaching practices is possible. For example, it is possible to engage instructional designers for online instruction development, create rich cases for problem-based learning, and create renewable energy problem sets for power systems courses that engage students in thinking about the purpose of the content they are learning. In addition, GEARED would benefit from a stronger focus on course assessment. For example, ensuring course objectives are assessed in a manner compatible with the level of the cognitive taxonomy that they are stated in (knowledge, understanding, application, etc.) would help to ensure the attainment of those objectives. Particularly for objectives that relate to economic and market integration aspects of renewables (which may require prerequisites from other fields), it is important to specify the level that these objectives should be stated and to assess them accordingly. A useful direction for the program to take would include more assessments of student preparedness and learning outcomes in addition to the existing attitudinal assessments of students' perception of the courses.

The DTTCs have addressed curriculum sharing in different ways. Universities are not well-structured for official course sharing. In some instances, individual universities tried to develop their own basic courses in power systems. However, they could have used knowledge from similar existing courses at partner universities to better utilize synergy between the partner universities. Looking forward, there are opportunities to develop repositories of curricular material for universities across the three DTTCs and outside of the DTTCs. IREC has been promoting the curricular efforts of the DTTCs and may have a valuable role in coordinating cross-consortium curriculum sharing.

Sharing curriculum for the short courses seems to be more problematic. Although short courses are seen as revenue generators and routes to sustainability for GridEd, MARMET has provided continuing education for local utilities without fees. Moving forward, it is important that the public investment in curricular development be reflected in the openness of the curriculum materials to the public. The broadest and nearest-term impact of the GEARED program will come from professional development and curricular change throughout the power system industry. The reviewers encourage the DTTCs to consider creating a plan for dissemination which honors Intellectual Property needs, program sustainability, and widest impact for the program. In the end, it may be the free sharing of all curricula that creates a sustained transformation of the utility and the power system industry.

4 For context, see for instance NYSERDA PON 3404 (https://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3404-Electric-Power-Transmission-and-Distribution-Distributed-Energy-Resource-Integration) and also the Flexible Interconnection Capacity Solution (FICS) NY REV demonstration project (http://www3.dps.ny.gov/W/PSCWeb.nsf/All/B2D9D834B0D307C685257F3F006FF1D9?OpenDocument).

## 3.2 Industry Engagement

Utility and industry involvement has been a priority across the GEARED network. Utility and industry stakeholders provide support, mentorship, and employment for GEARED students. In addition, they are actively involved in curriculum development and implementation. Future efforts should focus on expanding industry representatives to include diverse perspectives relevant to the GEARED program goals, such as solar developers, and involving industry more deeply in outreach efforts.

GEARED encourages face-to-face interactions between industry and students that goes beyond sponsoring conference travel and senior design projects. The industry advisory boards at the respective GEARED consortia engage with the student representatives during GEARED and consortia meetings. Industry and utility partners report being impressed with GEARED students and see their interactions as immediately beneficial. For example, several industry members commented that students' research provided solutions for existing problems within their organizations. Industry also provides internship opportunities that include a mentorship component.

Industry participates in the curriculum by identifying needs and participating as guest lecturers. In addition, students are exposed to real-world issues during field trips to utility installations and systems. There has been excellent engagement and coordination of DTTCs in recognizing basic power systems course needs and how fundamental these are to accelerating renewable energy deployment. However, there will continue to be a need to balance GEARED priorities for basic undergraduate training with graduate training and utility needs. For example, using graduate research to define GEARED goals is in contrast to utilities wanting to hire more undergraduates.

In the future, GEARED should engage more diverse stakeholder groups to address grid integration challenges. Relevant stakeholder groups include:

- Renewable energy developers – who are interested in methods to improve cost effective interconnection;
- Policymakers and regulators – who want to address changing utility business models and skills/workforce development;
- All groups within utilities – for example, planning, IT/OT, control automation, operations engineers, customer facing/DG interconnection, utility of the future/R&D etc.

Lastly, the outreach activities in GEARED are limited. The limited enrollment in power systems courses and the desperate need industry partners articulated for power systems engineers are evidence that outreach and recruitment of students into power systems majors is a necessary part of workforce development. The GEARED DTTCs have a rich opportunity for addressing this aspect of workforce development. By highlighting the renewable energy innovations that are part of the next generation, the DTTCs can motivate prospective engineers and pre-engineering undergraduates to engage in a power systems engineering degree program. Students and industry members made it clear during the review that "renewable energy is the dessert," which can tempt students to finish the foundational power systems courses and thus fill workforce gaps that industry members are particularly interested in.

## 3.3 Student Engagement

GEARED provides formal, as well as informal, opportunities to increase the employability of graduating students. Formal opportunities include attending conferences and participating in internships. The primary informal student activities supported by the GEARED program occur through SIBs, either as the primary participants or through the SIB leadership. However, there is a need for more structure associated with the SIBs (such as clear target activities SIBs can work towards) and increased emphasis on outreach to increase the pipeline of students pursuing power systems engineering.

All of the DTTCs have spear-headed formal programs focused on networking and employment opportunities. These programs include:

- The Summer Institute, featuring site visits to live energy generation plants (e.g. coal and natural gas plants, solar fields, and wind farms) and deep dives into relevant modern topics in power systems engineering, such as graph theory (FEEDER)

- Web portal for job opportunities and scholarships, which also links to EPRI's Careers page and IEEE PES Careers page (GridEd)
- IEEE SPAx event at NAPS 2016 in Denver focused on engineering and public policy (MARMET SIB)
- Power Engineering Conference at Illinois (PECI) – promotion increased participation by 45% in 2016 compared to 2015 (MARMET)

Informal programs, such as the SIBs, also provide opportunities for students to develop leadership and inter-personal skills, which make them more employable. The SIBs are an active and important part of all three consortia. A strength is that half to greater than half of the participants are undergraduate students. SIBs have been involved in planning and executing many face-to-face events, particularly embedded within conferences or professional meetings. These seem to be excellent opportunities for networking, industry/utility interaction, and professional development.

The SIBs are a great resource for engaging new students in renewable energy and power systems. However, this resource is utilized unevenly between DTTCs. All DTTCs lack formal or structured mentorship for students engaged in SIBs. Students in SIBs have excellent opportunities to present to industry, engage in outreach, and network with fellow students, but to take full advantage of these opportunities students need structured feedback and support. For example, asking students to do presentations is not a sufficient instructional tool to teach presentation or communication skills. Students only learn by doing if they get feedback on the quality of their skills development. In a typical interaction, social norms prevent industry mentors from correcting students who are not communicating effectively. The SIBs, with direct mentorship from industry participants, could be a high quality vehicle for providing feedback on presentations and social interaction to which students rarely have access.

In addition, the need for excited and engaged undergraduate students in power systems seems clear. However, students, faculty, and industry noted that students are brought into renewable energy and power systems very late in their undergraduate careers. Programs are supporting student involvement in experiential education, which could involve freshman as well as senior students, creating a larger pipeline of students for advanced courses. Across DTTCs, women and underrepresented minorities (URMs) are a largely untapped resource and lack critical role models for taking leadership positions within industry. For this reason, specific attention needs to be paid to cultivating a diverse group of leaders for the future. Veterans are also an untapped resource. There are a multitude of organizations, federal programs, and community organizations dedicated to helping veterans enter the workforce. Specialized outreach to transitioning members of the military as well as veterans already at universities could significantly increase the numbers of students interested in power systems.

## 3.4 GEARED Internal Evaluation

There is limited evaluation of GEARED efforts beyond midterm course evaluations. Academic metrics have been limited to quantity, rather than quality of courses. There is also a need to collect data on outcomes, such as student employment, and evaluate other aspects of the program, such as the SIB efforts. Current metrics are included in the Appendix.

IREC has engaged with DTTCs to address variances in workforce/curriculum gaps and GEARED performance metrics. However, due to DTTCs' differences regarding how they prefer to report such metrics, inconsistencies and inadequate data remain. Ongoing internal evaluation will be needed to consider new and revised metrics to understand course quality, student interest, retention, improved employment prospects, etc. In addition, on-going internal evaluation will be needed to consider new and revised metrics to evaluate GEARED performance relative to SunShot metrics. Any evaluation efforts need to mitigate data noise, in that metrics should count additive or unique outcomes due to GEARED and remove background noise data.

One potential solution to address this problem is to adopt the Accreditation Board for Engineering and Technology (ABET)-style of evaluation, which uses a matrix as shown in Figure 1. Instead of ABET outcome definitions, outcome definitions specific to GEARED can be developed. This would provide an additional measure to track academic impact by observing how and to what extent the courses collectively cover the GEARED outcomes.

| Outcome indicators & core courses | Outcome 1 | Outcome 2 | Outcome 3 | Outcome 4 | Outcome 5 | Outcome 6 | Outcome 7 |
|---|---|---|---|---|---|---|---|
| Portfolio | 3 | 3 | 3 | 3 | 3 | 3 | 2 |
| FE Exam | 3 | | | | | | |
| GPA | 1 | | | | | | |
| GPA in CHE | 2 | | | | | | |
| Design course: Project report | 2 | | 3 | | 3 | 1 | 2 |
| Design course: Oral presentation | 2 | | 3 | | 3 | 2 | 2 |
| Exit interviews with seniors | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Alumni interviews | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| ENGR 101 (Freshman engineering) | | | 1 | 1 | 1 | 1 | 2 |
| CS 110 | | 1 | | | | | |
| ENGL 112 (Freshman composition) | | | | | 1 | | |
| ENGL 365 (Technical writing) | | | | | 3 | | |
| CHE 205 | 3 | | | | 2 | 2 | |
| CHE 311 | 3 | | 1 | | | | |
| CHE 312 | 3 | | 1 | | | | |
| CHE 315 | 3 | | | | | | |
| CHE 316 | 3 | | | | | | |
| CHE 330 (Engineering laboratory) | 2 | 3 | | | 2 | 3 | 2 |
| CHE 410 (Engineering & society) | | | | 3 | 2 | | 2 |
| CHE 446 | 3 | | 1 | | | | |
| CHE 425 | 3 | | 2 | | | | |
| CHE 450 | 3 | | 2 | | | | |
| CHE 451 (Capstone design course) | 3 | | 3 | | 3 | 3 | 2 |

1 = objective addresses outcome slightly, 2 = moderately, 3 = substantively

Outcome 1: Ability to apply mathematical, scientific, and engineering principles to the identification, formulation, and solution of engineering problems

Outcome 2: Ability to design and conduct experiments & to analyze and interpret data using modern engineering tools and techniques

Outcome 3: Ability to design engineering processes and products to meet desired needs

Outcome 4: Ability to analyze important social and environmental problems and identify and discuss ways that engineers might contribute to solutions, including technological, economic, and ethical considerations in the analysis

Outcome 5: Ability to communicate effectively in both writing and speaking in a variety of professional contexts

Outcome 6: Ability to function effectively in both single-discipline and multidisciplinary teams

Outcome 7: Recognition of need for and ability to engage in lifelong learning

*Table 3. Program outcome assessment matrix.*

Figure 1. Example of ABET criteria matrix.[5]

It is also important to measure the non-academic aspects of GEARED. Outcome metrics such as employment and internship data are not collected in a centralized manner. Although this is a resource-intensive effort, it is a strong indicator of the success of the program. It may be possible to work with University career offices or ask students to update their information through the GEARED portal after completion of each academic year. In addition, it is important to measure the impact of the SIBs. The SIBs create excellent opportunities for networking, industry/utility interaction, and professional development. However, there are no metrics that indicate the value of these events for the students or the effect of these activities on students' employment plans or feelings of connection with the industry.

During the review meeting, one industry representative mentioned that the students graduating from GEARED universities are better prepared than other students. The FEEDER reported that all of their SIB alumni were placed in the workforce or continued graduate studies. It is not clear, however, how the DTTCs determine who a GEARED student is or how industry/utilities identify a GEARED student when hiring. The definition of a GEARED student should go beyond the SIB members (as students in the SIBs are less than 10% of the students impacted by GEARED) for post-education tracking purposes.

5 Felder, R.M. and R. Brent. (2003). Designing and Teaching Courses to Satisfy the ABET Engineering Criteria. *Journal of Engineering Education*, 92(1): 7–25.

# 4 Individual Awardee Performance

## 4.1 IREC

IREC, as the NNA, has provided the consortia with a national GEARED website, which provides an overview of each of the programs, the student innovation board members, GEARED news, and a GEARED calendar, as well as an intranet for GEARED courses, documents, meeting notes, metrics reports, and social media. The GEARED program utilizes an effective communication mechanism across the consortia through the development of the GEARED Executive Committee (GEC). IREC brings this group together for three meetings per year coordinated around relevant technical meetings. Overall design of the program with IREC as the coordinating agent has worked effectively in bringing the three DTTCs together to make GEARED a cohesive program. Looking to the future, IREC is best suited to spearhead efforts to improve course sharing, provide SIBs more structure, and collect improved metrics for evaluation.

### 4.1.1 Strengths

The scope of the GEARED program is impressive. Management of these diverse projects is a massive task. IREC has expertise concerning "branding" and translation of scientific research to novices/public, a useful quality in an NNA. The quality and quantity of educational products developed, academic/utility/industry relationships fostered, student engagement and employability goals achieved, and demand for program graduates is impressive. These outcomes are indicative of a very productive program, which cannot be possible without a productive NNA. Although IREC has not built new courses, they have provided support for evaluation. While some of the efforts are appropriate, the focus on evaluation seems to be more tilted towards quantity and less on quality. It is also concerning that IREC was not mentioned by the DTTCs as part of their presentations or their reports. It may be an artifact of the reporting process, but it is worrisome that IREC is not seen as central to the DTTCs' productivity by the DTTC principal investigators (PIs).

IREC's support of the DTTCs' engagement of academic and professional organizations is a significant and positive feature of the program. It was unclear that IREC had a direct role in the promotion or engagement of industry for curriculum development or utilization of the professional development opportunities offered by the DTTCs. IREC has enabled effective industry and student engagement in the GEARED program through the active participation in conferences and support for student attendance therein. The representation and presentations of the GEARED program and features at conferences like SPI, DistribuTECH, and other utility-facing conferences is bringing the message to the customer. IREC's work on enabling the GEARED "Educating, Hiring, and Developing the Next Generation of Electric Power Engineers" Mega Session at the DistribuTECH 2017 meeting is to be commended and shows the impact, interest, and participation of industry with the GEARED network. This has brought industry to the table and has resulted in significant buy-in with the GEARED program, resulting in ample industry feedback on program direction and curricula as well as numerous internships and mentoring opportunities for students within the GEARED network.

Additionally, through the GEC, the NNA has provided a platform for discussion around what is working in each consortium and how this can be adopted and applied in others. Finally, the NNA has developed a set of common metrics across the consortia that are being tracked and reported to quantify the impact of the GEARED programs. Additional gap analysis areas may need to be carried out via NAA engagement with the DTTCs in order to address course/curriculum development and especially short courses to address today's existing grid integration of distributed renewable energy challenges. IREC has shown responsiveness to DOE feedback for mid-project changes, specifically the GEARED website and SIBs engagement. The reviewers suggest continuing to push DTCCs to further engage consortium members to address grid integration challenges and diverse stakeholder group needs (e.g. renewable energy developers and methods to improve cost effective interconnection; policy/regulators to address utility business models; utility IT/OT & real-time systems; utility control engineers & operations engineers; etc.). IREC should continue pushing on the DTTCs for better engagement with undergraduate students early in their studies to create interest and excitement about how they can transform the grid. The reviewers recommend pushing on GridEd to share Spanish-language curriculum with other DTTCs as a way of furthering collaboration.

IREC seem seems to be actively innovating throughout the GEARED project. Their instructional intervention (midterm evaluations) is an innovative support for course development and instruction. Although it seems obvious, facilitated interactions between students (especially undergraduates) and industry at professional meetings is in fact innovative in the engineering education space. While much of the innovation responsibility remains with the DTTCs (i.e. course revision/creation/delivery), IREC is a trusted member of the industry that can leverage GEARED for additional innovation for accelerating grid integration of renewable energy. The reviewers suggest IREC (with DTTCs) publish a report on the current skills/training gap and suggest changes to address industry needs.

### 4.1.2 Areas for Improvement

IREC is playing an important role in overseeing and coordinating the DTTC efforts. Existing challenges in defining what is a power systems engineer, ensuring consistency, and promoting collaboration exemplify the need for GEARED, as well as having a NNA connected throughout the industry.

The primary area for improvement is in evaluation, which will require cooperation from the DTTCs. Coordination of accountability has clearly been a contentious aspect of their responsibilities, so these comments may more reflect issues across DTTCs and not IREC. The existing metrics, however, do not seem to be sufficient to evaluate the quality of the stated goals for each of the programs.

Ongoing effort will also be needed to support program sustainability post-DOE funding (e.g. FEEDER/MARMET). These efforts are critical to addressing the skills gap affecting grid integration challenges today and especially under high renewable energy deployment scenarios.

IREC can also facilitate ongoing efforts to evaluate the need for new courses and curriculum. Sustained effort will be needed to push and coordinate DTTCs on re-evaluating gaps given the changes during a five year program. IREC should also continue pushing on DTTCs for creating market value for a GEARED skillset (e.g. certificate of completion, LinkedIn badge, grid modernization "certification").

IREC should also continue to expand the type of stakeholders engaged in GEARED. There is a notable lack of solar and renewable energy developers, which should be an opportunity to extend the value of GEARED in this area as well demonstrate the commonalities between developers and utilities. The NNA, through its website, has provided a portal for different external target audiences and markets to be able to take advantage of different resources, activities, and news regarding the three different DTTCs. It should be pointed out, however, that the portal "resources" section is not sufficiently reflective of the material that different DTTC's have made available to external users.

## 4.2 MARMET

MARMET is administered through an executive committee formed of the lead from each institution, which meets via monthly conference calls. Additionally, consortia communications are organized through the MARMET annual retreat, which is an in-person meeting for all co-PIs; intercampus visits, which include visiting faculty seminars typically through videoconferencing; and learning events, including workshops and short courses; as well as meetings at national conferences. While MARMET has a strong regional focus, the consortium could be improved by increasing structure and coordination.

### 4.2.1 Strengths

The primary strength of the MARMET Consortium is the regional focus. The Midwest is an often "left out" area of the country and economic transformation is critical. The innovative instruction, building of laboratory infrastructure, effective use of existing resources, and student R&D projects are particular strengths. Their connection to industry is bolstered through their partnership with NRECA, which is strongly tied to supporting the energy cooperatives providing outreach and professional development opportunities. They have provided a number of opportunities for students to engage with industry through field trips and conference participation. For example, MARMET is organizing a networking event at the TechAdvantage expo to help build relationships between universities and electric coops.

The MARMET DTTC has focused on revising their power systems curricula to incorporate renewable and distributed generation modules and lectures. This is done in part through student research projects, from undergraduate demonstration projects to graduate level power systems research activities. They have also developed and taught short courses and held workshops on relevant topics that have been well received and attended by industry. Among the DTTCs, MARMET's incorporation of policy and communication skill development was strongest. A number of courses addressed economic and market aspects of renewable integration in addition to the intermittency and integration concerns addressed as part of the classical power systems engineering curriculum. All universities placed strong emphasis on renewable integration aspects in their courses with the exception of the following three UIUC courses which did not list renewable energy integration topics: ECE 498 (Power Distribution System Analysis; new course), ECE 554 (Dynamic system reliability; new course), and ECE 530 (Analysis Techniques for Large-Scale Electrical Systems; revised course).

Senior design projects had a strong focus on renewable integration issues faced by the utilities. The significant use of online/distance/continuing education is an important need (i.e. utility engineers need skills development for grid modernization) and is an effective innovation method for engaging students on high renewable energy penetration challenges. In addition, we suggest continuing investment and utilization of Open Modeling Framework (OMF) approach and its utilization in GEARED courses.

### 4.2.2 Areas for Improvement

MARMET resources have been focused on the development of laboratory equipment, resources for student research, and infrastructure for renewable energy curriculum. These resources are focused by necessity in the laboratories and schools that are part of GEARED. However, it is not clear who has been the driver of the investments that have been made. Are industry, faculty needs, course gap analysis, or student needs driving these changes and investments? The programs are clearly renewable energy focused, but the integration of renewable energy and microgrids to larger power systems projects is not present.

The member universities have modified the existing courses to introduce relevant new content, but many are minor revisions. There is no evidence of pedagogical innovation in the courses. While the undergraduate projects are very innovative and relevant, some of the graduate projects didn't seem to have a direct link to the project theme. The team members are highly qualified and they have leveraged appropriate industry connections for success of the project. A few short courses were developed with a utility focus. However, it is not clear the degree to which industry/utility needs filtered back into course development. The reviewers suggest learning from FEEDER's success with a course sharing model for ongoing engagement and sharing of course materials/resources.

A formal structure to the SIB could enhance communication and related activities. MARMET's SIB program has focused on creating impressive opportunities for face to face interaction. However, it is not clear how many students are an active part of the SIB. The students the reviewers spoke with felt connected to the SIB and were impressive. Only four students and two activities were given to us in the report. It is hard to know the true scope of activities based on these samples. Many of the projects are student generated, but it is unclear how the SIBs provide feedback to DTTC leadership that flows back into activity and curricular development.

Although the program has an impressive number of women on the SIB, it is not possible to make an assessment of the inclusion of minorities or veterans. To transform the industry, you need to transform who works in the industry. The program has been quite innovative in the development of projects and practices; the reviewers encourage the PIs to apply that creativity to expanding the workforce pool. It may be effective to focus on recruitment and outreach efforts through veterans' association, yellow ribbon school, and minority serving institutions.

MARMET does not have an outreach mission. Outreach at the high school and freshman undergraduate student levels would seem particularly appropriate for GEARED's workforce development mission. Although it is not part of the project objectives, the type of projects (e.g., solar village) students are engaged in seem well suited for outreach activities. It is also hard to image how the program will achieve goals concerning increasing the power systems workforce if the number of engineering majors (HS outreach) and power systems majors or content experts are not increased. The reviewers recommend that MARMET make K-12 outreach more of a priority.

MARMET has an informal structure compared to the other two DTTCs. A more formal structure for MARMET could be useful. For example, MARMET could consider forming an Advisory Committee of industry representatives and meet with them on a regular basis (at least once per year).

Ongoing effort will be needed to support program sustainability post-DOE funding. The reviewers suggest further industry involvement (e.g. funding and/or a formal advisory board) for DTTC administration and collaboration if GEARED is producing more effective new hires. The sustainability plan is very generic and relies mainly on existing programs. The team should consider some new initiatives for long –term sustainability of the project.

## 4.3 GridEd

GridEd is administrated by EPRI and is structured to routinely evaluate and maximize its impact toward the GEARED program goals. GridEd is leveraging EPRI's collaborative relationships with both universities and member utilities, to expand these relationships and provide active educational opportunities across this interface to train both current and future power systems engineers. Their administration is thorough and deliberate in their aim to transform the landscape of the electric industry through a sustainable training and education program for power engineers. Their growth is targeted toward enabling utilities/industry to partner with local universities in order to leverage these existing relationships against the GridEd network and resources and thereby resulting in a growing education and outreach network that is driven and valued by the utilities GEARED is meant to serve. These affiliate universities then have access to GridEd curriculum materials and resources to more rapidly develop relevant courses in the new institutions being engaged in the GridEd network.

### 4.3.1 Strengths

GridEd effectively leveraged existing relationships to quickly support GEARED goals, with the opportunity for additional utility engagement (e.g. short courses) to EPRI's non-GEARED members. Courses cover the full spectrum of subjects in three traditional power system engineering tracks that also address intermittency and integration issues. Different delivery formats were utilized as needed. There was excellent engagement with members to have curriculum translated and offered in Spanish. The sustainability plan is clear and realistic.

Dedicated courses addressing market and economic aspects including those related to renewable energy technologies have been developed. A notable exception is the Clarkson University course, EE 535 (Power System Reliability), which is a new course. No topic related to reliability implications of renewables is listed. Conceivably, it is an interesting addition to the topics of the course but it may be that research in this area is not mature enough to be developed into the course as this may not have been included in the GE MARS software platform that the course relies on.

GridEd has innovated on the GEARED model in terms of utility/university engagement through their affiliate university program. The initiative requires new utility members to bring on their preferred regional universities to join and benefit from the GEARED network capabilities. This helps to build out the radius of influence that GridEd can have on the field and on the customer. This very effectively leverages the GEARED program to extend well beyond the core members and provides regional education and recruitment opportunities for the participating utility members. Industry directly engages with students at conferences where meetings are held. It seems more industry engagement could be sought outside of conferences.

EPRI is very successful in engaging students. EPRI's significant ($5,000) support for undergraduate projects is a highlight of industry involvement. It provides an opportunity for students to experience the project proposal aspect of R&D as well as elevating what is possible for the scope of undergraduate projects. In addition, GridEd has a large and engaged SIB cohort. The SIB serves as outreach, advocacy, and leadership within this DTTC. The level of involvement, both as a function of the number of partner universities involved, the number of students involved, and the wide range of projects is impressive.

GridEd has the most extensive outreach mission of the three DTTCs. This mission is supported by Georgia Tech's long-standing tradition of K-12 outreach. GridEd has taken full advantage of existing programs and leveraged them to meet their mission. One exciting new addition is the Teacher Training program. The reviewers encourage the designers of these programs to ensure that teachers have the resources (classroom materials and supplies) to support teachers' applications of what they learn as part of the program.

### 4.3.2 Areas for Improvement

GridEd is a highly productive group with many parts moving at the same time. However, it is not clear that these parts move in harmony. Students do not identify with GridEd (although some do understand their engagement with GEARED). There are many activities, which are unique to one institution only. The resources may only be capable of being leveraged at one institution, but the spread of ideas and instructional innovations does not seem to be part of the picture. Clarity/ongoing effort will be needed to address limitations and risks that exist in EPRI's operating model (e.g. EPRI is perceived as being a utility representative) compared to overall energy industry needs with respect to high renewable energy penetration scenarios. GEARED itself supports bridging this gap, with the ongoing need to ensure effective management of diverse stakeholder needs (e.g. utility business models; DER developers/financiers; all ratepayers/society; etc.). GridEd seems more focused on supporting the existing industry than transforming the industry.

GridEd has modified existing courses as well as introduced new courses. However, some courses seem to be very traditional with little relevance to the scope of the project. Also, in some cases, the effort at different universities seems to be duplicated unnecessarily. More synergy and interaction between the partner universities on course content will alleviate this concern. Also, there is no evidence of introducing new pedagogy in the courses. Course development and design may be well tied to industry needs, but that does not necessarily mean they are innovative. In some cases, that is just the opposite. The industry/utilities need students with "fundamentals". In some cases, this means simply developing power systems courses for the first time. Revision of the power systems courses seems to reflect the existing (rather than future) technology. While there is a need for traditional power systems course topics, the reviewers suggest further consideration of course topics to meet GEARED goals for skills development on high renewable energy penetration. In addition, the assumption that students will be change agents requires further evaluation – effective change agents will need more direct mentoring/training in behavior sciences.

GridEd does not engage in curriculum sharing. The reviewers recommend learning from FEEDER's success in the course sharing model for ongoing engagement and broad dissemination of materials/resources.

Student engagement could also be improved. The web portal for student job opportunities is valuable, but the work seems to duplicate the work of IEEE PES. The SIBs need additional mentoring and formal structure to engage students more actively within, as well as outside of, their respective universities. There is also little diversity in the SIB. To support the next generation of industry leaders it is critical that they have opportunities for leadership as part of their formative experiences. There is a lack of vision concerning the diversification of the workforce, and the scale of changes to curriculum, professional development, and professional support to get this done is a concern. To transform an industry you have to do better than average. The discussion of diversity in GridEd SIBs was not encouraging in terms of the populations involved. The reviewers recommend that GridEd put a greater emphasis on developing a diverse student body and diverse SIBs.

Although the development of interest in power systems is a stated goal, the outreach efforts seem to replicate what already exists. There is not a clear and concerted effort to extend the workforce through inclusion of untapped resources such as veterans, women, and minorities. Going forward one way to improve innovation is to consider inclusion of yellow ribbon schools, targeted fellowships and travel support from GridEd.

## 4.4 FEEDER

FEEDER is administered by the University of Central Florida. FEEDER depends on the PI for overall management and has designated individuals with responsibilities of education, utility interaction, SIB activities and reporting. The Steering Committee of the project has as members: PIs of each of the collaborating institutions and representatives from each of the partner federal labs. Membership in the Advisory Committee of the project includes deans of the colleges involved in this effort and representatives from industry, utilities, and national labs. The Steering Committee meets the Advisory Committee yearly to report on their progress and seek advice for future activities. FEEDER is building a strong network between students and industry stakeholders.

### 4.4.1 Strengths

There are some very strong elements of FEEDER. The strategic expansion utilizing the Solar Training and Education for Professionals (STEP) program, strong student advocacy (especially concerning internship guidance), innovative course developments, and support for undergraduate research are all critical elements. Additionally, the ability to articulate the difficulties faced by students wishing to enter the power systems field and obstacles they will need to overcome provide good pathways for the future.

The FEEDER consortium is addressing especially relevant topics of grid modernization and renewable integration in a region of the US where these are larger challenges with the utilities being more averse to change. The work they have been doing to educate students and power systems professionals is therefore very important for increasing the adoption of renewable resources on the grid in this region. The expansion to the west and environments outside of the southeast is being leveraged appropriately and will hopefully continue to provide lessons learned for making this transition in the utilities more informed and therefore effective.

A number of courses address economic and market aspects of renewable integration in addition to intermittency and integration concerns addressed from the engineering standpoint. The two University of Pittsburgh revised courses – ECE 1771 (Electric Machinery Fundamentals) and ECE 2250 (Introduction to Power Electronics) – do not include topics on renewable integration although they are very relevant to these courses. For example in ECE 1771, examples of applications of synchronous and asynchronous machines in wind turbines are relevant and in ECE 2250, DC to DC converters utilized in the PV industry provide good case studies. Strong industry partner engagement and collaboration with National Labs in addition to student design projects with industry-relevant topics are indicative of a curriculum informed by and contributing to industry goals.

The course materials repository and course-sharing agreements are great. The valiant efforts to create true shared courses is laudable. These links have the opportunity to create lasting networks across universities. Additionally, the faculty have identified their own areas of expertise, and lack of expertise, to optimize the use of the consortium as a whole. FEEDER has worked to get course sharing agreement in place and will have 7 FEEDER institutions on board starting in spring 2017. More STEP/FEEDER institutions are planning to join the course sharing effort as their approvals go through the various institutions. FEEDER has monthly teleconferences with the 12 partner institutions, bi-annual meetings at conferences, and summer programs.

FEEDER has strong industry participation (particularly with Siemens) in student presentations and research. Students are supported in creating GEARED-focused internships and students continue their association with industry partners after the program is finished. There is a strong network developing here. There seems to be a strong student cohort. The students that reviewers spoke with had a sense of where undergraduates were working and had maintained contact with them. There is no better indication that a true network is being formed.

FEEDER provides interactions with industry and students through collaborative R&D projects and by providing expertise on problem solving or programmatic research. The industry advisory boards suggest, and provide mentorship for, student design projects through technical as well as financial support. There are frequent industry guest lectures on campus as well as industry-hosted visits and internships during summer programs. In particular, up to 30 students recently participated in visits to nine industry partners over a period of a week, where they received in-person perspectives on how their coursework is relevant in the field. There are extensive internship opportunities with a major pull from industry to get students out to visit and engage.

FEEDER has strong extracurricular learning activities. The Summer Institutes are a very innovative way to engage students. NREL provides a high-quality hands-on learning experience. This activity could be an opportunity to connect GEARED students across projects by opening up this experience to all GEARED participants. Inclusion of service learning activities, such as Engineers Without Borders, is also a nice feature. There is a possibility here for support from industry members as mentors for service learning projects. The existing level of support for these projects and level of student participation is not clear.

FEEDER has a remarkable SIB program. There is a specified faculty mentor and the inclusion of alumni in the SIB provides students with valuable peer mentorship in the transition from school to the workforce. The frequency of SIB meetings and the active representation of all institutions in the SIB is also laudable. In addition, the SIB is a useful venue for evaluation. The students, and especially alumni, have unique and valuable information concerning "what works" in the courses they have taken and the types of informal educational activities available to them.

### 4.4.2 Areas for Improvement

The team went through a detailed analysis to determine gaps in existing curricula at partner universities. They used this information to modify existing courses as well as introduce new courses. However, their focus seems to be on quantity rather than quality. While several courses have new content, some new courses are traditional with no content relevant to renewable energy. More synergy and exchange between partner universities would address these issues. FEEDER should continue effort on new courses and multi-disciplinary collaboration (e.g. distributed and autonomous control; systems integration interoperability/communications protocols – IT/OT; controllability & observability of underdetermined systems; etc.). The lack of inclusion of solar developers as industry partners/advisers as well as the limited emphasis on high penetration solar energy as part of the curriculum may limit the relevance of the program changes for the primary goals of the program. In addition, although some of the courses are very novel, there was no evidence of introducing new pedagogy in these classes. The reviewers recommend developing additional short courses to further engage industry – especially given how existing utility personnel will need smart grid training/collaboration to address high renewable energy penetration goals. Lastly, on-going effort will be needed to support program sustainability post-DOE funding. The reviewers suggest further industry involvement (e.g. funding) to support a viable sustainability plan to the program after DOE funding has ended.

Although the development of interest in power systems is a stated goal, the outreach efforts seem to replicate what already exists. Although the program has a stronger inclusion of women (it is not possible to make an assessment of the inclusion of minorities or veterans with the data provided) than is common for power engineering programs, there is still room for improvement. Going forward, one way to improve innovation is to consider inclusion of yellow ribbon schools, targeted fellowships and travel support from FEEDER. In addition, to create and extend the existing workforce, students need to be attracted to power systems, renewable energy, and distributed generation early. Outreach to freshman college students as well as high school students would fill a need articulated by industry, faculty, and students during this review.

# 5 Recommendations

## 5.1 Overall

The reviewers provided the following recommendations across the whole portfolio:

Curriculum Development & Sharing

- Implement innovative teaching practices to provide more engaging learning experience (e.g. experiential learning)
- Promote curriculum sharing
- Collaborate on smart grid courses and curriculum (see p 6-7)
- Provide mentoring and training in behavior sciences to help students/professionals be "change agents" within their organizations
- Engage existing industry professionals (e.g. through expanded mid-career training opportunities) to encourage change and innovation at higher, more established levels of organizations in the short-term
- Increase focus on course assessment
- Create a plan for dissemination which honors Intellectual Property needs, program sustainability, and widest impact for the program

Industry Engagement

- Balance GEARED priorities for basic undergraduate training with graduate training and utility needs
- Engage more diverse stakeholder groups to address grid integration challenges (e.g. renewable energy developers)
- Perform outreach to motivate prospective engineers and pre-engineering undergraduates to engage in a power systems engineering degree program

Student Engagement

- Increase structure associated with the SIBs (e.g. clear target activities SIBs can work towards)
- Perform outreach to increase the pipeline of students pursuing power systems engineering
    - Increase diversity (e.g. women, veterans, transitioning military and underrepresented minorities)
- Provide feedback on presentations and social interactions through SIBS

GEARED Internal Evaluation

- Collect and evaluate new and revised metrics to understand course quality, student interest, retention, employment, SIB efforts etc.
- Evaluate GEARED performance relative to SunShot metrics
- Clarify definition of GEARED student

## 5.2 Award-Specific

The reviewers made the following recommendations for each award:

IREC

- Spearhead efforts to improve course sharing, provide SIBs more structure, and collect improved metrics for evaluation

- Encourage DTTCs to engage with undergraduate students early in their studies to create interest and excitement about how they can transform the grid
- Encourage GridEd to share Spanish-language curriculum with other DTTCs as a way of furthering collaboration
- Publish a report on the current skills/training gap and suggest changes to address industry needs
- Support program sustainability post-DOE funding (e.g. FEEDER, MARMET)
- Encourage DTTCs to create market value for a GEARED skillset (e.g. certificate of completion, LinkedIn badge, grid modernization “certification”)
- Expand the type of stakeholders engaged in GEARED (e.g. renewable energy developers)
- Post material that different DTTC’s have made available to external users to portal “resources” section

MARMET

- Continue investment and utilization of OMF approach and its utilization in GEARED courses
- Learn from FEEDER’s success with a course sharing model for ongoing engagement and sharing of course materials/resources
- Provide a formal structure to the SIB to enhance communication and related activities
- Increase recruitment and outreach efforts (e.g. through veterans’ association, yellow ribbon school, and minority serving institutions)
- Make K-12 outreach more of a priority
- Increase industry involvement for DTTC administration (e.g. formal advisory board)
- Plan for program sustainability post-DOE funding (e.g. industry funding)

GridEd

- Increase industry engagement outside of conferences
- Encourage the designers of the Teacher Training program to ensure that teachers have the resources (classroom materials and supplies) to support teachers’ applications of what they learn as part of the program
- Increase synergy and interaction between the partner universities on course content
- Increase course topics to meet GEARED goals for skills development on high renewable energy penetration
- Provide mentoring and training in behavior sciences to help students/professionals be “change agents” within their organizations
- Learn from FEEDER’s success in the course sharing model for ongoing engagement and broad dissemination of materials/resources
- Increase recruitment and outreach efforts (e.g. through veterans’ association, yellow ribbon school, and minority serving institutions)
- Put a greater emphasis on developing a diverse student body and diverse SIBs by providing targeted fellowships and travel support

FEEDER

- Develop additional short courses to further engage industry (e.g. smart grid training/collaboration to address high renewable energy penetration goals)
- Plan for program sustainability post-DOE funding (e.g. industry funding)

- Increase recruitment and outreach efforts (e.g. through veterans' association, yellow ribbon school, and minority serving institutions)
- Put a greater emphasis on developing a diverse student body and diverse SIBs by providing targeted fellowships and travel support
- Make K-12 outreach more of a priority

# 6 Appendix

## 6.1 Peer Review Meeting Attendees

Table 2. List of peer review meeting attendees and affiliations.

| | |
|---|---|
| **Department of Energy** | |
| Dave Rench McCauley | DOE |
| Elaine Ulrich | DOE |
| Shubha Jaishankar | DOE |
| Stephanie Kline | DOE |
| **Interstate Renewable Energy Council (IREC)** | |
| Joe Sarubbi | IREC |
| Larry Sherwood | IREC |
| Mary Lawrence | IREC |
| Matt Champagne | IREC |
| **MARMET** | |
| Mariesa Crow | Missouri University of Science and Technology |
| Hao Zhu | University of Illinois Urbana-Champaign |
| Diane Rhodes-Michaely | NRECA |
| Mike Casper | NRECA |
| **GridEd** | |
| Agustin Irizarry-Rivera | University of Puerto Rico - Mayaguez |
| Badrul Chowdhury | University of North Carolina – Charlotte |
| Steven Coley | EPRI |
| Tanguy Hubert | EPRI |
| Tom Reddoch | EPRI |
| **FEEDER** | |
| Roger Dougal | University of South Carolina |
| Zhihua Qu | University of Central Florida |
| **Reviewers** | |
| Jeremiah Miller | DOE SunShot |
| Parhum Delgoshaei | Penn State University |
| Jenefer Husman | University of Oregon |
| Anil Pahwa | Kansas State University |
| Dana Olson | DOE SunShot |

## 6.2 Course List

Table 3. Courses modified or created by GEARED DTTCs listed by awardee and university. New versus revised courses are noted. This list was generated from reports provided by awardees prior to the Peer Review event as well as data reported to IREC.

| Course Name | University | Awardee | New? | PD? |
|---|---|---|---|---|
| Economic systems for electric power planning (EE 458) | Iowa State University | MARMET | No | No |
| Electromechanical Wind Energy Conversion & Grid Integration (EE 459/559) | Iowa State University | MARMET | No | No |
| Energy Systems and Power Electronics (EE 303) | Iowa State University | MARMET | No | No |
| Energy Systems Planning (EE 552) | Iowa State University | MARMET | No | No |
| Introduction to Energy Distribution System (EE 455) | Iowa State University | MARMET | No | No |
| Advanced Power Electronics (ELEC ENG 6520) | Missouri University of Science and Technology | MARMET | No | No |
| Computer Methods In Power System Analysis (ELEC ENG 6540) | Missouri University of Science and Technology | MARMET | No | No |
| Electric Power Quality (ELEC ENG 5550) | Missouri University of Science and Technology | MARMET | No | No |
| Introduction to Systems Engineering/Marketing Systems Analysis/Supply Chain Systems (EMGT 2310, 3510, 5614) | Missouri University of Science and Technology | MARMET | No | No |
| Photovoltaic Systems Engineering (ELEC ENG 5150) | Missouri University of Science and Technology | MARMET | No | No |
| Power Electronics (ELEC ENG 5520) | Missouri University of Science and Technology | MARMET | No | No |
| Power Electronics Laboratory (ELEC ENG 5521) | Missouri University of Science and Technology | MARMET | No | No |
| Power System Operations (ELEC ENG 6580) | Missouri University of Science and Technology | MARMET | No | No |
| Power System Protection (ELEC ENG 6560) | Missouri University of Science and Technology | MARMET | No | No |
| Power System Reliability (ELEC ENG 6530) | Missouri University of Science and Technology | MARMET | No | No |
| Power Systems Engineering (ELEC ENG 5540) | Missouri University of Science and Technology | MARMET | No | No |
| Supply Chain Management Systems (EMGT 5614) | Missouri University of Science and Technology | MARMET | No | No |
| Analysis Techniques for Large-Scale Electrical Systems (ECE 530) | University of Illinois | MARMET | No | No |
| Electric Machinery (ECE 431) | University of Illinois | MARMET | No | No |
| Green Electricity (ECE 333) | University of Illinois | MARMET | No | No |
| Power Circuits and Electromechanics (ECE 330) | University of Illinois | MARMET | No | No |
| Advanced Power System Analysis (ECE 731) | University of Wisconsin | MARMET | No | No |
| Utility Application of Power Electronics (ECE 714) | University of Wisconsin | MARMET | No | No |
| Senior Design Course (Illinois ECE 445, Missouri EE 4096/4097, Iowa EE 491/492) | Illinois, Missouri, Iowa | MARMET | Yes | No |
| Power system analysis II (EE 457) | Iowa State University | MARMET | Yes | No |
| Wind Energy System Deployment (WESEP 512) | Iowa State University | MARMET | Yes | No |
| Wind Energy System Design (WESEP 511) | Iowa State University | MARMET | Yes | No |
| Dynamic system reliability (ECE 554) | University of Illinois | MARMET | Yes | No |
| Power Distribution System Analysis (ECE 498HZ) | University of Illinois | MARMET | Yes | No |
| Power Distribution Systems Analysis (ECE 498) | University of Illinois | MARMET | Yes | No |
| HEV and EV Power Electronics (seminar) | University of Wisconsin | MARMET | Yes | No |
| Parallel Grid Connected (seminar) | University of Wisconsin | MARMET | Yes | No |
| Special Topics in Power Systems: Power Electronic Systems for Sustainable Energy (ECE 905) | University of Wisconsin | MARMET | Yes | No |
| V2G (seminar) | University of Wisconsin | MARMET | Yes | No |

| Course Name | University | Awardee | New? | PD? |
|---|---|---|---|---|
| Engineering Economics for Utilities (short course) | Iowa State University | MARMET | No | Yes |
| Distributed Generation and Microgrids (short course) | Iowa State University | MARMET | Yes | Yes |
| Distributed Generation Integration (EPRC short course) | N/A | MARMET | Yes | Yes |
| Distribution Protective Relaying (EPRC short course) | N/A | MARMET | Yes | Yes |
| Best Practices for Effective Community Solar Communications (online) | NRECA | MARMET | Yes | Yes |
| Communication Networks for AMI and Advanced Distribution Automation (online) | NRECA | MARMET | Yes | Yes |
| Cooperative Experiences with Community Solar (online) | NRECA | MARMET | Yes | Yes |
| DER Resources: Planning, Implementing, and Maintaining Utility-Scale PV (online) | NRECA | MARMET | Yes | Yes |
| Distributed Generation Interconnection (online) | NRECA | MARMET | Yes | Yes |
| Emerging Energy Issues (online) | NRECA | MARMET | Yes | Yes |
| How Electric Cooperatives are Integrating Solar (online) | NRECA | MARMET | Yes | Yes |
| Lessons Learned from Utility-Scale PV and Community Solar Deployments (online) | NRECA | MARMET | Yes | Yes |
| The Solar Panel: Position Your Co-op as the Trusted Energy Partner (online) | NRECA | MARMET | Yes | Yes |
| Utility solar tools, including OMF (online) | NRECA | MARMET | Yes | Yes |
| Microgrid Systems and Power Electronics for Low Energy Buildings (workshop) | University of Illinois | MARMET | Yes | Yes |
| Grid Connected Inverters (seminar) | University of Wisconsin | MARMET | Yes | Yes |
| Introduction to Electrical Energy Storage Devices and Systems (short course) | University of Wisconsin | MARMET | Yes | Yes |
| Power Electronics Design Boot Camp (short course) | University of Wisconsin | MARMET | Yes | Yes |

| Course Name | University | Awardee | New? | PD? |
|---|---|---|---|---|
| Electrical Energy Systems (ECE 3072) | Georgia Institute of Technology | GridEd | No | No |
| Power System Engineering (ECE 4321) | Georgia Institute of Technology | GridEd | No | No |
| Electric Power Distribution Systems II (ECGR 6145/8145) | University of North Carolina, Charlotte | GridEd | No | No |
| Energy Markets (ECGR 4172 / 5172) | University of North Carolina, Charlotte | GridEd | No | No |
| Introduction to Energy Systems (ECGR 4171) | University of North Carolina, Charlotte | GridEd | No | No |
| Power Electronics (ECGR 4144 / 5144) | University of North Carolina, Charlotte | GridEd | No | No |
| Utility Applications of Power Electronics (ECGR 4090 / 5090) | University of North Carolina, Charlotte | GridEd | No | No |
| Design of Transmission and Distribution Systems (INEL 5406) | University of Puerto Rico - Mayaguez | GridEd | No | No |
| Advanced Topics in Energy Power Systems (EE 536) | Clarkson University | GridEd | Yes | No |
| Deregulated Power Systems (EE 554) | Clarkson University | GridEd | Yes | No |
| Market Operation of Power Systems (EE 534) | Clarkson University | GridEd | Yes | No |
| Power System Reliability (EE 535) | Clarkson University | GridEd | Yes | No |
| Distributed Generation and Energy Storage (ECGR 4090 / 5090) | University of North Carolina, Charlotte | GridEd | Yes | No |
| Power Quality (ECGR 6173 / 6090 / 8090) | University of North Carolina, Charlotte | GridEd | Yes | No |
| Distributed Energy Resources (INEL 6995) | University of Puerto Rico - Mayaguez | GridEd | Yes | No |
| Distributed Generation and Storage Technologies and Applications (short course) | N/A | GridEd | No | Yes |
| Dynamic Distribution System Modeling with OpenDSS (short course) | N/A | GridEd | No | Yes |
| Applications of Smart Inverter Technology (short course) | N/A | GridEd | Yes | Yes |
| Business Case Analysis (short course) | N/A | GridEd | Yes | Yes |
| DG Interconnection on Radial Distribution Systems (short course) | N/A | GridEd | Yes | Yes |
| Distributed Generation Technologies and applications (short course) | N/A | GridEd | Yes | Yes |
| Dynamic Distribution System Modeling (short course) | N/A | GridEd | Yes | Yes |
| Electric Power Distribution Systems (short course) | N/A | GridEd | Yes | Yes |
| IEEE 762 (short course) | N/A | GridEd | Yes | Yes |
| Unbalanced Distribution System Analysis (short course) | N/A | GridEd | Yes | Yes |

| Course Name | University | Awardee | New? | PD? |
|---|---|---|---|---|
| Global Energy Issues (EGR 240) | University of Kentucky | FEEDER | No | No |
| Smart Grid – Automation and Control of Power systems (EE532) | University of Kentucky | FEEDER | No | No |
| Electric Machinery Fundamentals (ECE 1771) | University of Pittsburgh | FEEDER | No | No |
| Introduction to Power Electronics (ECE 2250) | University of Pittsburgh | FEEDER | No | No |
| Power Distribution Systems Engineering and Smart Grids (ECE 1710) | University of Pittsburgh | FEEDER | No | No |
| Power Systems Analysis II (ECE 2774) | University of Pittsburgh | FEEDER | No | No |
| Digital Controls for Power Electronics (ELCT891) | University of South Carolina | FEEDER | No | No |
| Power Systems Design and Analysis (ELCT 551) | University of South Carolina | FEEDER | No | No |
| Introduction to Renewable Energy (ELEC 5970/6970) | Auburn University | FEEDER | Yes | No |
| Integration of Distributed Generation (EEL 5288/EEL 5930) | Florida State University | FEEDER | Yes | No |
| Control of Electric Power Systems (ELEG 5473) | University of Arkansas | FEEDER | Yes | No |
| Design of Advanced Power Distribution Systems (ELEG 5503) | University of Arkansas | FEEDER | Yes | No |
| Power and Energy Systems Analysis (ELEG 4513/5513) | University of Arkansas | FEEDER | Yes | No |
| Advanced Topics in Power Engineering – Power Distribution Engineering (EEL6269) | University of Central Florida | FEEDER | Yes | No |
| Advanced Topics in Power Engineering – Power System Resilience (EEL6269) | University of Central Florida | FEEDER | Yes | No |
| Communications and Networking for Smart Grid (EEL5268) | University of Central Florida | FEEDER | Yes | No |
| Complex Network and Smart Grid (Summer Institute) | University of Central Florida | FEEDER | Yes | No |
| Data Analytics in Power Systems (EEL6XXX will be offered in Fall 2017) | University of Central Florida | FEEDER | Yes | No |
| Distributed Control and Optimization for Smart Grid (EEL5291) | University of Central Florida | FEEDER | Yes | No |
| Global Energy Issues (EEL4932ST) | University of Central Florida | FEEDER | Yes | No |
| Introduction to Smart Grid (EEL4932) | University of Central Florida | FEEDER | Yes | No |
| Power Systems Operations (Summer Institute) | University of Central Florida | FEEDER | Yes | No |
| Smart Grid: Abnormal Condition (Summer Institute) | University of Central Florida | FEEDER | Yes | No |
| Smart Grid for Sustainable Energy (EEL4218) | University of Florida | FEEDER | Yes | No |
| Advanced Power Systems (EE641) | University of Kentucky | FEEDER | Yes | No |
| Integration of Photovoltaics in Modern Power Systems (ELCT554) | University of South Carolina | FEEDER | Yes | No |
| Special Topics in Distributed Energy Resources for Electric Energy Systems (ELCT 559) | University of South Carolina | FEEDER | Yes | No |
| Integrating PV into Smart Grids (Professional Training) | University of Central Florida | FEEDER | Yes | Yes |
| Microgrid Concepts (Summer Institute) | University of Central Florida | FEEDER | Yes | Yes |
| Planning and Engineering for Distributed Generation (Short Course for Engineers) | University of Central Florida | FEEDER | Yes | Yes |
| Planning and Standards (Summer Institute) | University of Central Florida | FEEDER | Yes | Yes |
| Utility Concerns with High Penetration PV (Lakeland Electric) | University of Central Florida | FEEDER | Yes | Yes |
| Fracking in Kentucky (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| From Solar Cars to the Industrial Development of Axial Flux Electric Motor Technology (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| Future of Energy Efficiency in the home (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| Half a Century of UK and UPT Contributions to the Theory and Technology of Electric Machines and Drives (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| Rapid Changes in Energy (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| The Clean Power Plan and its Effect on Kentucky (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| The Dawn of Infotricity: Combining Electric Power and Information (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| The Future Grid and the Integration of Renewables (seminar) | University of Kentucky | FEEDER | Yes | Yes |
| Why I am (still) in favor of nuclear power (seminar) | University of Kentucky | FEEDER | Yes | Yes |

## 6.3 Reported Metrics

Table **4**. Academic curriculum metrics. The number of students enrolled are not unique counts.

| Awardee | Students Enrolled | Courses Delivered | New Courses | Revised Courses |
|---|---|---|---|---|
| MARMET | 2,042 | 81 | 11 | 23 |
| GridEd | 4,898 | 155 | 7 | 8 |
| FEEDER | 7,118 | 299 | 19 | 8 |

Table **5**. Professional development curriculum metrics. The number of professionals enrolled are not unique counts.

| Awardee | Professionals Enrolled | Courses Delivered | New Courses | Revised Courses |
|---|---|---|---|---|
| MARMET | 2,941 | 29 | 17 | 1 |
| GridEd | 262 | 15 | 8 | 2 |
| FEEDER | 341 | 14 | 14 | 0 |

Table **6**. Student engagement metrics. The total student attendance are not unique counts.

| Awardee | Events | Total Student Attendance | Grads | Undergrads |
|---|---|---|---|---|
| MARMET | 20 | 225 | | |
| GridEd | 29 | 352 | 185 | 167 |
| FEEDER | 358 | 1,353 | | |

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