Building the Essential Online Power Quality Course

A Demonstration

3002023450

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Technical Update, April 2022

EPRI Project Manager

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ABSTRACT

The strain of adding new, distributed sources of electricity to the bulk power system is exposing new power quality (PQ) problems, as is the influx of new electrical and electronic loads. The fast pace of electrification is accelerating the emergence of those problems. Unfortunately, the university system is not keeping up with the surge in demand for PQ education and training, and most online courses in power quality are tied to specific commercial products or services. Electric utilities must be more nimble than ever in their efforts to generate, transmit, and distribute perfect sine waves to their customers. EPRI proposes to develop an online PQ training course to enable utility engineers, technologists, and technicians to work confidently in power quality. As a nonbiased curator of PQ problems and their solutions—based on decades of field, laboratory, and collaborative research—EPRI, working with its distance-learning division (EPRI|U), is the ideal administrator of a new online course to train PQ staff how to deal with the emerging challenges of a modern grid. The Power Quality Certificate Training (PQCT) course will be designed to educate existing engineers, technologists, and technicians to become power quality engineers, technologists, and technicians. This thorough and technically rigorous course would approximate a one-semester, three-credit college course comprising 12 course modules, including fundamental modules in PQ monitoring, the various PQ phenomena, methods of mitigation, grid support, and troubleshooting. This technical update describes the work done over six months, including conducting competition research, conducting a survey of Program 1 advisors, and building a demonstration video, which was played during the 2022 Winter Advisory Meetings.

Keywords
Power Quality
Training Course
Education

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The strain of adding new, distributed sources of electricity to the bulk power system is exposing new power quality (PQ) problems, as is the influx of new electrical and electronic loads. The fast pace of electrification is accelerating the emergence of those problems. Unfortunately, the university system is not keeping up with the surge in demand for PQ education and training, and most online courses in power quality are tied to specific commercial products or services. Electric utilities must be more nimble than ever in their efforts to generate, transmit, and distribute perfect sine waves to their customers. EPRI proposes to develop an online PQ training course to enable utility engineers, technologists, and technicians to work confidently in power quality. As a nonbiased curator of PQ problems and their solutions—based on decades of field, laboratory, and collaborative research—EPRI, working with its distance-learning division (EPRI|U), is the ideal administrator of a new online course to train PQ staff how to deal with the emerging challenges of a modern grid. The Power Quality Certificate Training (PQCT) course will be designed to educate existing engineers, technologists, and technicians to become power quality engineers, technologists, and technicians. This thorough and technically rigorous course would approximate a one-semester, three-credit college course comprising 12 course modules, including fundamental modules in PQ monitoring, the various PQ phenomena, methods of mitigation, grid support, and troubleshooting. This technical update describes the work done over six months, including conducting competition research, conducting a survey of Program 1 advisors, and building a demonstration video, which was played during the 2022 Winter Advisory Meetings.

This course will feature modern adult-learning techniques, such as dynamic video for those who learn mostly by sight, real-world audio and video such as those rendered from bodycams, self-paced lessons, and immediate feedback on progress at every checkpoint. The course is designed for those in power quality programs who need a foundation for work in the field. As the course expands, it can be modified and targeted for:

- Industrial Customers
- Electricians
- Vendors and Manufacturers of PQ Equipment
- Utility Customer Service Engineers
- Utility Account Managers
- Utility Representatives
- The Public

One module per week: 12 weeks for entire course

- Prerecorded videos that mix:
  - Instructor Speaking
  - Digital Whiteboards with Voiceovers

    - Existing Videos and Audio as Content (Existing)
    - Animations
    - POV While Handling/Holding/Pointing to a Device (Bodycam)
    - Pop Quizzes
- Tests
- Work Assignments
- Reading Assignments
- Weekly Group Meetings with the Instructor

The Twelve Modules

The PQCT course will offer twelve modules over twelve weeks, approximating a university semester.

- Introduction to Power Quality
- Understanding PQ Monitoring
- PQ and the Customer
- Understanding Voltage Sags
- Understanding Voltage and Current Harmonics
- Understanding Voltage Flicker
- Understanding Voltage Transients
- Understanding Resonance
- PQ Mitigation Strategies for Loads
- PQ Mitigation Strategies for the Grid
- How to Practically Apply PQ Standards
- How to Safely Place and Configure a PQ Monitor in the Field

Faculty

Top power quality engineers will teach the twelve modules.

Tom Cooke

- Senior Technical Leader, EPRI
- Project Set B Manager: Integrating PQ Monitoring and Intelligent Applications to Maximize System Performance
- PQ TechWatch Author
- PQ Hotline Team and Author
- PQ Data Analysis and Management
- PQ Benchmarking
- High-Impedance Arcing Detection
- Stray & Contact Voltage

Roger Dugan

- Sr. Technical Executive
- PQ TechWatch author
- IEEE Fellow
- Decades of experience in distribution engineering
- Analysis of harmonics, transients, and utility distribution systems
- 2005 recipient of the IEEE Excellence in Distribution Engineering Award

Bill Howe

- Sr. Program Manager for Power Quality Research (Program 1)
- His professional interests include:
  - Analysis of harmonics, transients, and utility distribution systems
  - Demand response, electric energy efficiency, and market research
- Decades in management and senior engineering positions
- Experience in medium-voltage power quality product development, product testing

Mark McGranaghan

- Sr. Technical Executive
- IEEE Fellow
- PQ TechWatch author
- Decades of experience in distribution engineering
- Analysis of harmonics, transients, and utility distribution systems
- 2005 recipient of the IEEE Excellence in Distribution Engineering Award

Gaurav Singh

- Senior Technical Leader
- Project Set A Manager
- PQ TechWatch author
- PQ Hotline Team and author
- Conducted research and analysis of PQ problems
- Areas of interest include harmonic emission and compatibility issues created by single-phase power electronics-based loads

Mark Stephens

- Program Manager, PQ Services
- Over three decades of experience in industrial automation systems and PQ
- Chief architect of the PQ Investigator Expert software
- Project Set C Manager
- PQ Hotline Team and author of several PQ Encyclopedia chapters
- Taught over 60 industrial-related courses
- Written over 20 conference papers

This Phase of the Project

The EPRI supplemental project Power Quality Certificate Training is roughly divided into three phases. This, the first phase, included designing and implementing a survey of advisors of Program 1 and other utility engineers to garner the opinions of likely students of the course, managers of PQ groups, and others involved in power quality (Chapter 2). It also included conducting competition research to determine how the planned course aligns, exceeds, or falls short of the offerings of potential competitors (Chapter 3). Finally, the first phase culminated in a demonstration of the course contents, organization, teaching methods, instructors, and pedagogical expectations. The second phase will include a usability test of the PQCT's efficacy. A dozen or so volunteer students will take one module of the course—most likely on voltage sags—over a week while being monitored and questioned by proctors of the research. The feedback will inform the third phase, which includes standing up the entire course at EPRI|U.

2
SURVEY OF POWER QUALITY ADVISORS

On November 4th, 2021, EPRI launched and administered a survey that was taken by 24 respondents. The questions were designed and assembled, with the final draft reduced to seven questions with freeform fields attached to each answer (the last question was a freeform field, so it was not extended). This mix of numerical answers (quantitative) and written answers (qualitative) provided a wealth of information from the respondents. The survey instrument is included in Appendix A.

Survey Conception

The project management conceived a survey to inform the development of the course. The survey was designed and implemented to garner the opinions of likely students of the course, managers of PQ groups, and others involved in power quality.

Survey Design

The seven questions in the survey (shown in Appendix A) are pointed. Every sentence was built to be reader-ready, and the resulting survey questions were peer-edited in several rounds. Within a week after all editors expressed satisfaction, the survey was launched on November 4th, 2021.

Survey Results

On November 12th, 2021, EPRI gathered the quantitative and qualitative data from the company that provided the survey software. Thereafter, the data was analyzed. Below are the quantitative and qualitative results.

Quantitative Results

1. EPRI Program 1 (Power Quality) proposes the following twelve training modules for the final form of the PQCT. Please assign a weight to each module from 1 to 5, based upon your and your company's training needs, with 1 being “I don't think the course needs to provide any training on this subject” and 5 being “I think it is essential that the course provides training on this subject.”

All twelve proposed training modules were received well by the respondents. The average for each of the twelve modules is above 4.0/5.0, as shown in Figure 2-1. The modules that ranked highest are Introduction to Power Quality, Understanding Voltage Transients, and PQ Mitigation Strategies for Loads. The modules that ranked lowest are PQ and the Customer, Understanding Resonance, and How to Safely Place and Configure a PQ Monitor in the Field.

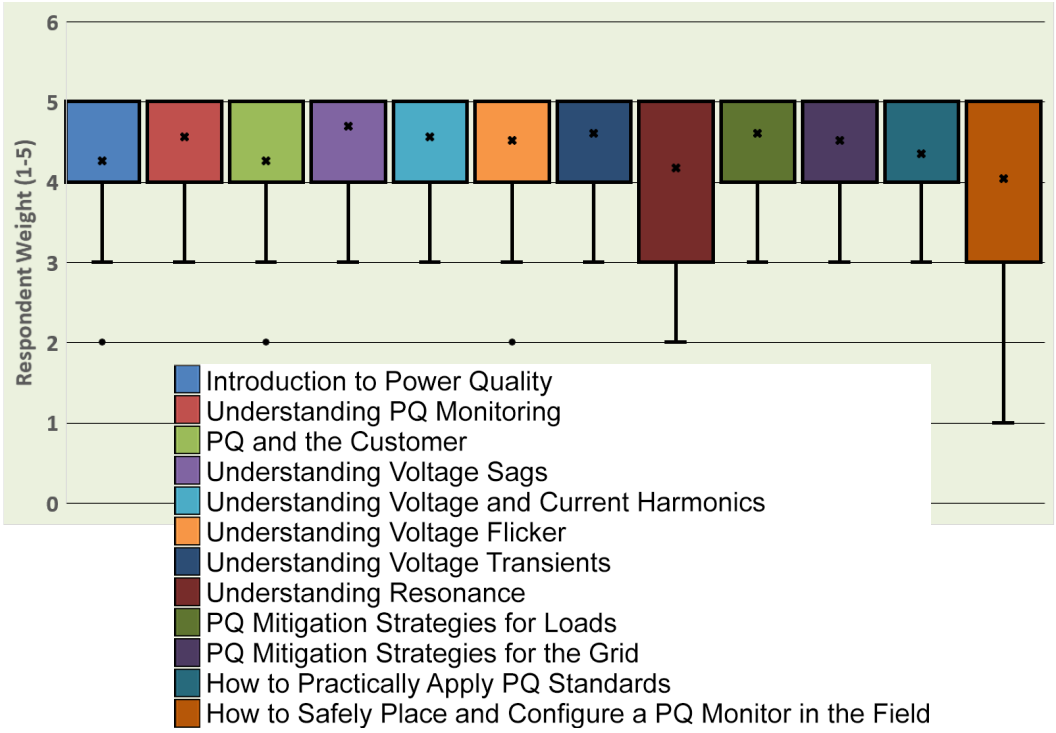

Figure 2-1
Quantitative results of survey question number 1

2. The course will likely be a mix of on-demand content and instructor-based lectures, with reading assignments and tests of knowledge throughout the course. Because we are trying to achieve the optimal mix, please assign a weight to each element below from 1 to 5, with 1 being “I don't find this element useful at all” and 5 being “I find this element extremely important.”

The results for this question varied widely, as shown in Figure 2-2. The modes of education that ranked highest are Lesson-Based Video Modules, Hands-on Instruction, and Moderated Peer Discussions. The modes that ranked lowest are Reading and Homework Assignments, Course Projects, and One-on-One Time with the Instructor.

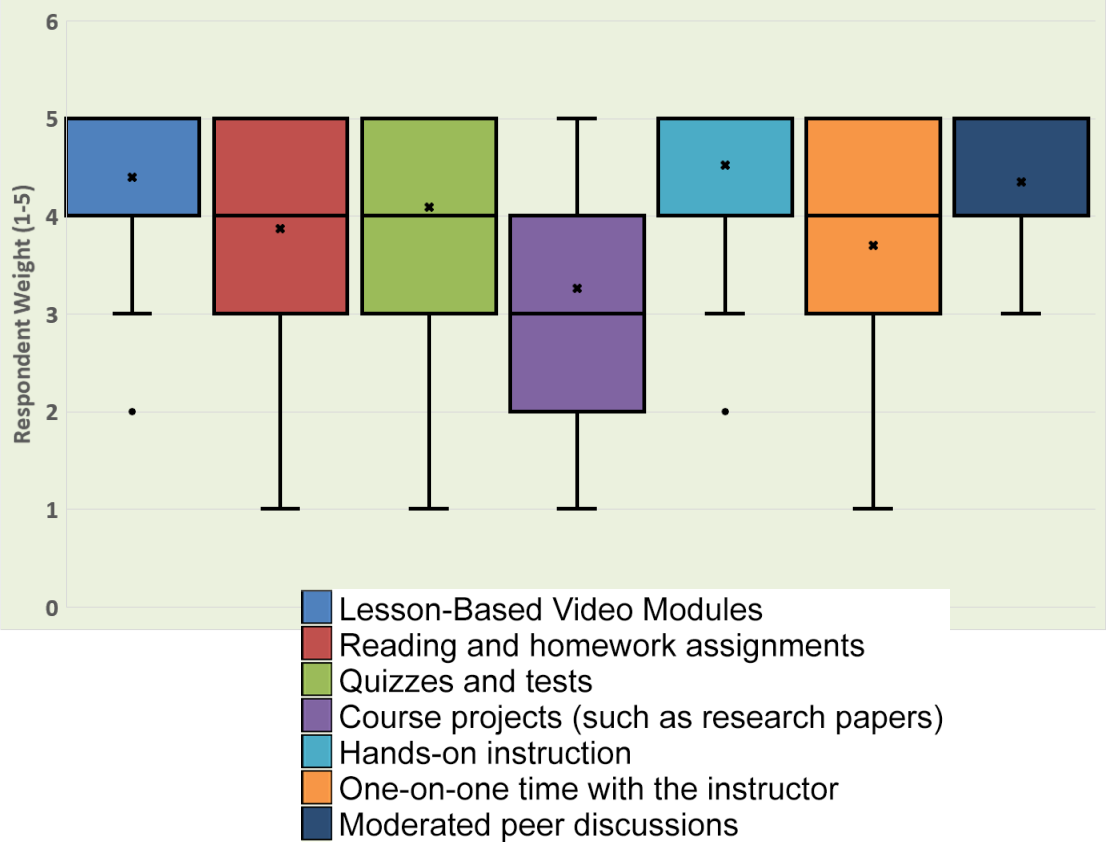

Figure 2-2
Quantitative results of survey question number 2

3. Writing assignments can reveal whether a student grasps the nuance of the technical content of the course, although they may also significantly increase the student's outlay of time outside the “classroom,” as well as the instructor's time grading them. Should writing assignments, such as technical essays, be combined with tests and quizzes to gauge student comprehension and recall?

The respondents were split on the answer to this question, with 10 saying that writing assignments should be integrated into the course, and 13 saying that they should not be integrated, as shown in Figure 2-3.

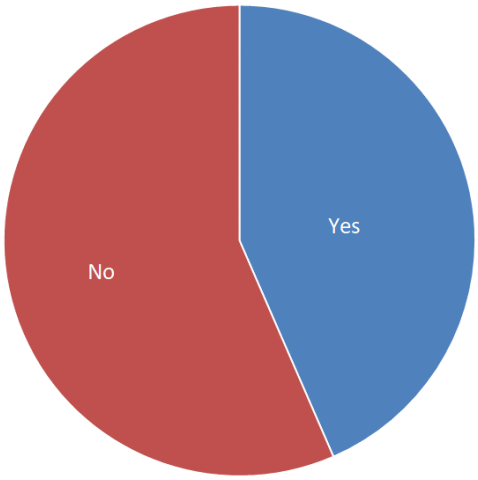

Figure 2-3
Quantitative results of survey question number 3

Please include the rationale for your answer.

4. Awarding a certificate of completion to a student requires measuring how well the student learned the course content. How should the performance of students be evaluated during the course? Please select one.

As shown in Figure 2-4, 9 respondents preferred that students be graded quantitatively (quizzes and tests), 7 preferred pass/fail, 6 preferred a combination of using quantitative and qualitative methods, and only 1 preferred being graded based on qualitative methods alone.

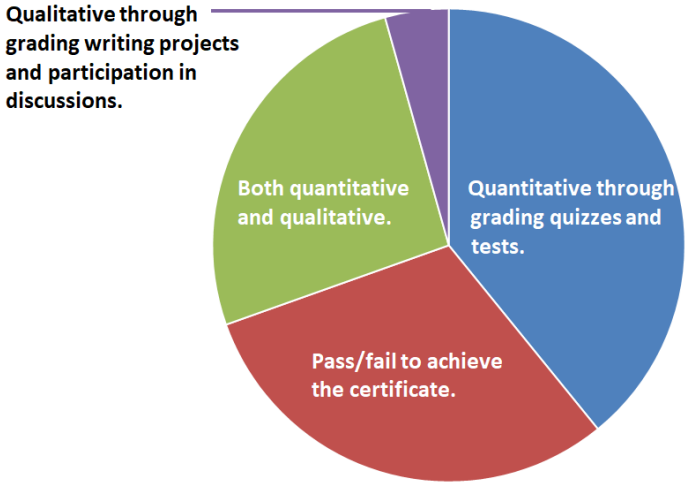

Figure 2-4
Quantitative results of survey question number 4

5. Should the PQCT employ group assignments, such as peer review and group homework?

The respondents were split on the answer to this question, with 11 saying that group assignments should be integrated into the course, and 12 saying that they should not be integrated, as shown in Figure 2-5.

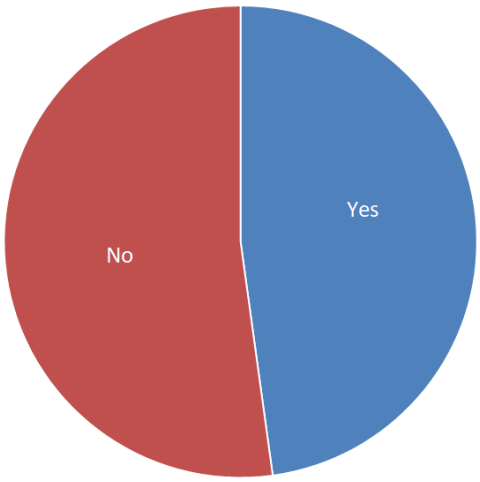

Figure 2-5
Quantitative results of survey question number 5

6. Many people learn primarily through vision. To facilitate this mode of learning, instructional videos can include the instructor handling real-world instruments (analyzers, CTs, PTs, PQ monitors, and so on), transmission and distribution components (circuit interrupters, reclosers, regulators, and so on), and industrial equipment (PLCs, relays, CVTs, and so on) while wearing a VR headset (such as RealWear) to enhance the student's point of view. However, this approach may significantly increase the cost of producing instructional videos and therefore increase the price of the course to students. Please assign a weight from 1 to 5 to how important such a virtual point of view would be to the proposed PQCT, with 1 being "not important at all" and 5 being "extremely important."

As shown in Figure 2-6, the respondents were lukewarm about the prospect of turbocharging the course with VR, with an average weight of 2.86. Suggested compromises and alternatives are shown in the Qualitative section below.

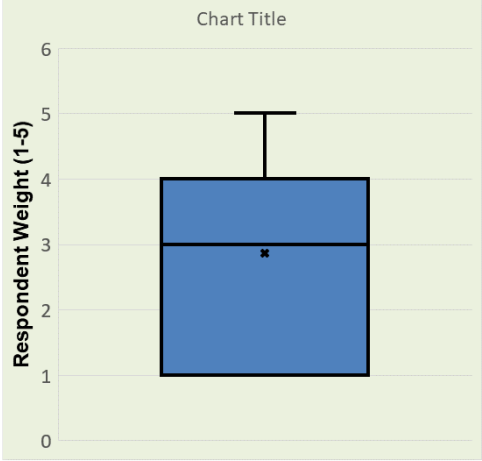

Figure 2-6
Quantitative results of survey question number 6

Qualitative Results

Each question encouraged respondents to provide additional information, which is included verbatim in Appendix B.

1. What other subjects would you like to see included in basic PQ training as standalone modules (either wholly new or extracted from one of the twelve proposed modules)?

Most of the subjects mentioned by the respondents will be included in the twelve modules as subordinate elements. For example, voltage imbalance will be introduced in "Introduction to Power Quality" and included in the two modules on "PQ Mitigation"; ferroresonance will be included in "Understanding Resonance"; and electrical measurements will be included in "Understanding PQ Monitoring." A summary of topics proposed by the respondents is shown below. Figure 2-7 shows how they map to the existing roster of PQCT modules.

Ferroresonance

Mitigating Resonance

Effects of Harmonics on Revenue Meters

Harmonics

Subharmonics

Interharmonics

High-Frequency Noise

Radiated Emissions (RFI, Electric & Magnetic Fields)

Voltage Imbalance

Converters and Their Effects on Frequency Spectrum in the Power System

Transformers (and Other Equipment)

Induced Voltages and Currents

Stray and Contact Voltage and Elevated Neutral-to-Earth Voltage

Grounding at Swimming Pools

Lightning-Mitigation Methods

Wiring and Grounding

The Consequences of Renewables and DER on the Grid

Understanding and Managing PQ Effects of Small-Scale LV Solar DG

PQ Effects of Larger-Scale Solar and Wind DG Connected at MV Levels

PQ Effects of Inverter-Based Battery Charging, EVs, and the Like

PQ Mitigation at the Transmission Level

Using a Computer Program to Identify Potential Problems

Basic Electrical Measurements

Electrical Parameters/Calculations/Measurements (Volts, Amps, Watts, Vars, RMS, Peak, Fundamental, Average, DC Offset, and So On)

Voltage Levels

Safety

PQ Reports for Customers Performing Customer Audits

Voltage Regulation (ANSI C84.1)

PQ Data (Configuration, Data Retrieval, Data Storage, Visualizations, Automation of Analytics and Reporting)

Process and Controls

The Future of the Grid

How to Specify and Vet New PQ Equipment

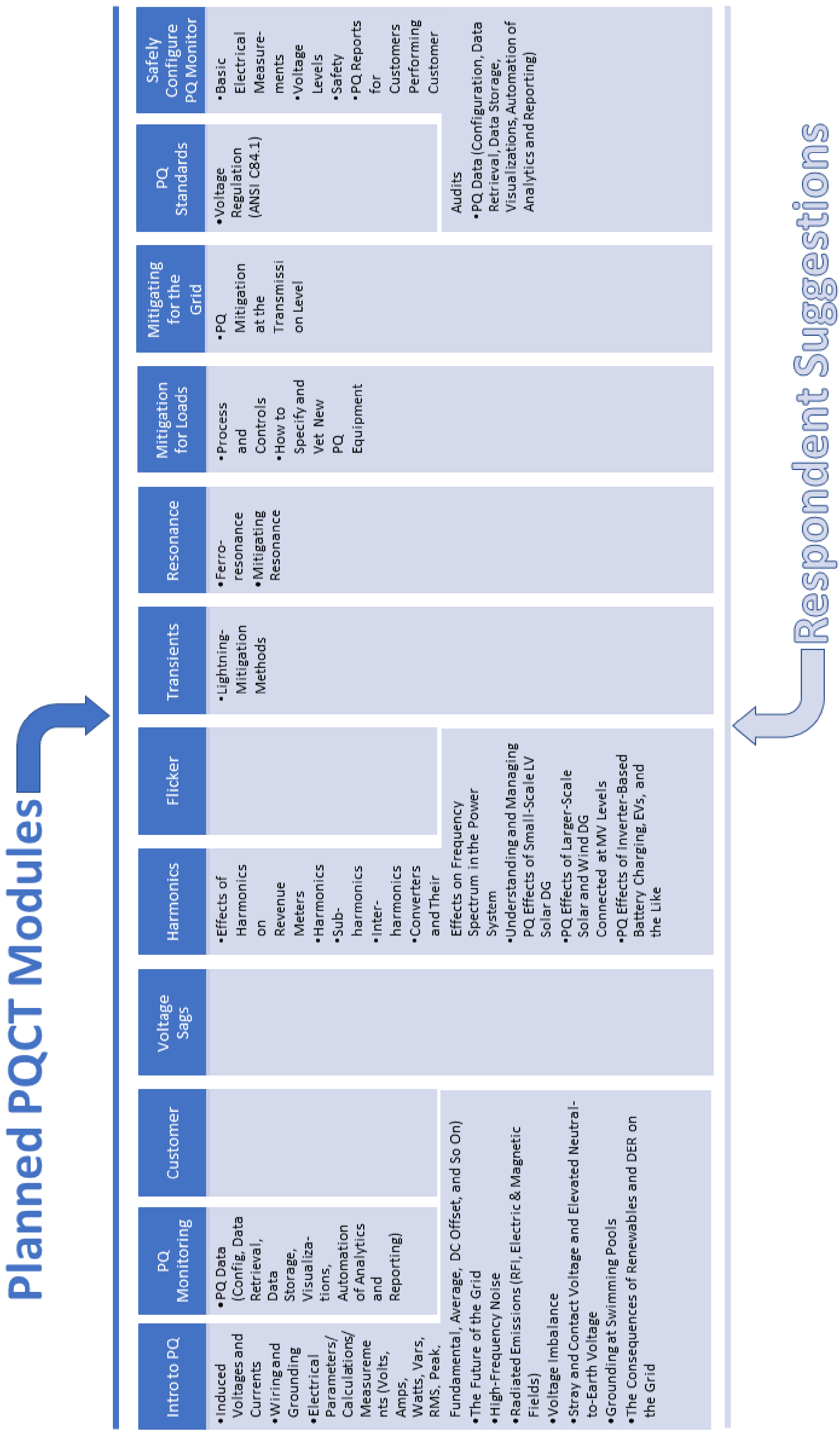

Figure 2-7
A map of topics suggested by respondents to the existing roster of PQCT subjects

2. What other kinds of training methods do you think that power quality training should include?

The respondents replied to this question with examples of training methods that have been or will be considered for the course:

- Peer Discussions of Anecdotal Experience (Telling Stories, Hands-On Instruction, and So On)
- PQ Lab and Field Exercises
- Writing Reports/Analysis of Exercises
- Lab Instruction
- Self-Paced (Prerecorded) Content
- Lessons from the Field (Such As Monitor Installations)
- In-Person Training
- Discussion Board for Student Interaction
- Issues Found in the Field

3. Please include the rationale for your answer to: Should writing assignments, such as technical essays, be combined with tests and quizzes to gauge student comprehension and recall?

The respondents were split on this subject, with 10 responding that there should be writing assignments, and 13 responding that there should not be writing assignments. Some answers were context-specific. For example, one respondent said that writing assignments are not suited for students pursuing certification; they are fine when certification is not the goal. Some included a rationale for their answers, such as, "Writing ensures understanding" and "Written explanation provides greater insights of the students understanding of the subject." One compelling argument against writing assignments is that "there can be a tendency to spend more time on the 'quality' of one's writing than deepening one's technical understanding of a topic."

4. What other kinds of progress evaluations seem appropriate for the proposed PQCT?

Beyond quizzes, tests, and exercises, respondents recommended presentations on PQ topics to the class and instructor and participation in discussions.

5. Please list any group activities that seem appropriate for the proposed PQCT.

One respondent suggested a type of field trip, that the course can incorporate the "use a facility like Lenox and stage a PQ problem." Other respondents emphasized laboratory and field exercises, which may be incorporable into the course. Another suggested having students write a white paper as a capstone to the course. One respondent asked, "Can you really get this certification without ever taking a measurement or inspecting a customer site?" While troubleshooting in the field is beyond the scope of this course, the question is relevant and deserves consideration. Perhaps one compromise is to make quizzes and tests practical, for example, testing students on their abilities to connect a meter to a polyphase transformer. One recommended a home-based monitoring project that requires students to record their experiences and share the results with a peer group or instructor during class.

6. Please list any other visual methods of instruction that you would like to see included in this course.

Several respondents believed that virtual headsets would be "hard to achieve." A compromise is a bodycam showing the POV of the instructor as he or she manipulates, sets up, and measures with a PQ monitor or conducts an industrial audit. Several students expressed a need to see real people using real PQ equipment and industrial components, which can certainly be fulfilled by the use of a bodycam. One student weakness predicted by several respondents is that students will likely not have any experience in the field, so capturing field work will be highly effective.

7. For you and your staff, what is the real-world application of achieving a certificate in power quality training? For example, how would people apply what they learn to their jobs? How important would completing such a course be to not only improving work performance but also advancing careers within your utility?

The respondents had various views of how a certificate from the PQCT could affect the lives and works of graduates, summarized in the bullet list below:

- The knowledge gained during the course must be immediately applicable.
- The certificate gives the students "street cred" and is a demarcation point for job applicants.
- This course could become part of an onboarding process for new utility hires.
- The course must be foundational, part of a worker's progression plan.
- The content should be something that the utility itself cannot handle.
- When a utility faces retirements and transfers and needs to hire non-PQ people to handle the work, this course would be a good way to transfer knowledge to them.
- The course certificate will have minimal impact and should be for personal improvement.
- This course will help in the areas of customer claims, grid planning and development, and gird maintenance.
- The PQCT will fill a gap in training for succession planning as PQ experts in the utility industry are retiring with limited natural succession opportunities.
- This course should be very useful in utilizing/developing PQ engineer skills and as an industry credential.
- This course and certificate will increase customers' trust in a utility's competence to solve their PQ problems.
- At some utilities you need a PE or CEM to move up to a principle role and having this would be a good substitute for those of us with technology degrees.
- Completing this course is not a career game changer or going to enable students to receive a higher paycheck.

Conclusions

Some of the survey respondents preferred "training" as opposed to "academic instruction"—a vocational/professional enterprise versus a university type of education. How do these preferences constrain the vocabularies of the modules? How do they constrain the content?

Students see the PQCT as a way to deliver “virtual hands-on” (pragmatic), rather than learning by rote (by viewing “canned” presentations). The respondents confirm the wide range of learning methods to be employed by the PQCT, including:

- Prerecorded videos that mix:
  - Instructor Speaking
  - Whiteboards with Voiceovers
  - Existing Videos and Audio as Content
  - Animations
  - POV While Handling/Holding/Pointing to a Device (Bodycam)
  - Pop Quizzes
- Tests
- Work Assignments
- Reading Assignments
- Weekly Group Meetings with the Instructor

3
COMPETITION RESEARCH

Although the competition research unveiled a dozen or so entities that offer some sort of PQ training, only the six companies shown in Table 3-1 are considered here; the others have no features comparable to the PQCT. Generally, the training offered by these companies fell short for two main reasons: None were comprehensive; many were tied to products. All of the PQ training courses reviewed for the PQCT project provided training online.

Eaton's link to its PQ training offering, shown in Table 3-1, is now dead, as is the training course itself. Some of the content ended up in a different training course called "Advanced Electrical Power System Studies." The rest of the URLs work.

As shown in Table 3-2, the properties vary broadly. For example, the cost of the course varies from free to $2,350; the duration from one hour to five days. In fact, the number of days versus the duration is practically linear, as shown in Figure 3-1. The most expensive course (Power Quality and Reliability by AZTech) does not offer CEUs and does not disclose whether any of their modules include live meetings. Still, it falls far short of the 12 weeks planned for the completion of the PQCT.

The course with the next highest cost is Power Quality Analysis Training by Electricity Forum. This course spans just two weeks. The AZTech course has only seven subjects in its course outline but five days to complete the $2,350 course. 360 Training does not disclose enough information about its PQ training course for a proper review.

Table 3-1
Competitors to the EPRI PQCT

Who	Where	What
Eaton	https://www.eaton.com/us/en-us/services/electrical-worker-training/remote-instruction/power-quality-course-details.html	Remote Instruction – Power Quality Monitoring and Analysis
The Electricity Forum	https://www.electricityforum.com/electrical-training/power-quality-training	Power Quality Analysis Training
360 Training	https://www.360training.com/course/8036-power-quality	8036 Power Quality
AZTech	https://aztechtraining.com/course/power-quality-and-reliability-2	Power Quality and Reliability Training
AVO Training	https://www.youtube.com/watch?v=X6k9fOfxlyg	Megger: An Introduction to Power Quality
Dranetz	https://www.dranetz.com/technical-support-request/dranetz-webcasts/	Five Modules Leaning into Monitoring Products

Table 3-2
Properties of the discovered and investigated PQ training courses

Company	Name of PQ Course	Cost	Live?	Course Duration	CEUs?	Certificate?
Electricity Forum	Power Quality Analysis Training	$499.00	Yes	2 Days	Yes 1.2	Yes
360 Training	8036 Power Quality*	$65.00	Not Disclosed	Not Disclosed	Yes 2 Hours NERC CEH	Yes
AZTech	Power Quality and Reliability	$2,350	Not Disclosed	5 Days	No	Yes
Megger	An Introduction to Power Quality	Free	No	1 Hour	No	No
Dranetz	Five Seminars	Free	No	5 Hours	No	No

*360 Training also sells topical PQ training, $65 for each module, such as "Power Factor" and "Impedance and Voltage Drop."

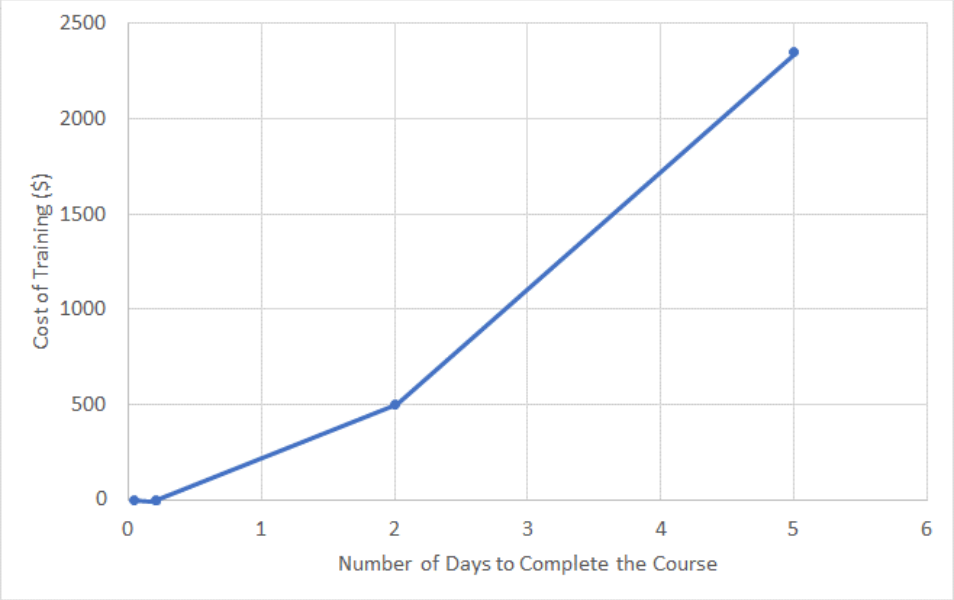

Figure 3-1
Cost versus number of days to complete a course

Comparing the PQCT's course outline to those of the companies listed in Table 3-1 led EPRI to believe that competitors do not have much content to convey to students. The content of the courses is compressed to fit it into a short schedule. For example, for $500, a student can take The Electric Forum's *Power Quality Analysis Training* over a period of two days. On the first day, students are taught 26 subjects. On the second day, 37 subjects. It is unlikely that students can thoroughly explore all 63 subjects over a period of 16 hours (that is 4 subjects per hour, or 15 minutes per subject).

A
PQCT SURVEY INSTRUMENT

Below is a survey that was developed and executed in October 2021. Beyond optionally providing name, company, and email, each of the 23 respondents from the 20 unique organizations shown below was asked to respond to seven questions regarding the building of the PQCT.

Alabama Power Company	Ameren Missouri
American Electric Power (AEP) - AEP OHIO	Central Hudson Gas & Electric
CPS Energy	Duke Energy
Entergy	EPRI
FirstEnergy	Indiana Michigan Power/AEP
LGE/KU	National Grid
Powerco Ltd (New Zealand)	PowerSouth Energy Cooperative
Salt River Project	State of California
TAURON Dystrybucja S.A.	Tri-State Generation and Transmission Association
Tennessee Valley Authority (TVA)	WEC Energy Group

Power Quality Certificate Training (PQCT)

THANK YOU

On behalf of the entire EPRI Power Quality Group, thank you for taking this survey. The results from you and other EPRI Program 1 advisors will significantly inform the Power Quality Certificate Training (PQCT) project, making the design and content of the course optimally relevant to power quality engineers, technicians, and technologists.

WHAT IS THE PQCT PROJECT?

The PQCT project is a training course proposed by EPRI Program 1. The course will address the PQ training needs within the electric utility industry and provide a base on which utilities can build a new generation of power quality experts. The immersive training will transform engineers, technicians, and technologists into Power Quality engineers, technicians, and technologists. Graduation from the course and conferment of a certificate of completion require about 150 hours of study, with about 36 hours of online instruction and the remaining hours devoted to outside work (such as reading assignments, quizzes, and tests). The development of the course will be the subject of a supplemental project. EPRI will circulate the official Supplemental Project Notice before the end of this year. Please answer the three personal-

identification questions on the next page before answering the seven survey questions on page three, which are designed to enable EPRI Program 1 advisors to advise EPRI about the desired form and content of the course. Once again, we thank you for participating.

Next

Answering the following three questions is not required. If you wish to remain anonymous, please skip to Question 1 on the next page by clicking the Next button.

1. Your name

2. Your utility

3. Your e-mail

Prev Next

1. EPRI Program 1 (Power Quality) proposes the following twelve training modules for the final form of the PQCT. Please assign a weight to each module from 1 to 5, based upon your and your company's training needs, with 1 being "I don't think the course needs to provide any training on this subject" and 5 being "I think it is essential that the course provides training on this subject."

	1	2	3	4	5
Introduction to Power Quality	○	○	○	○	○
Understanding PQ Monitoring	○	○	○	○	○
PQ and the Customer	○	○	○	○	○
Understanding Voltage Sags	○	○	○	○	○
Understanding Voltage and Current Harmonics	○	○	○	○	○
Understanding Voltage Flicker	○	○	○	○	○
Understanding Voltage Transients	○	○	○	○	○
Understanding Resonance	○	○	○	○	○
PQ Mitigation Strategies for Loads	○	○	○	○	○
PQ Mitigation Strategies for the Grid	○	○	○	○	○
How to Practically Apply PQ Standards	○	○	○	○	○
How to Safely Place and Configure a PQ Monitor in the Field	○	○	○	○	○

What other subjects would you like to see included in basic PQ training as standalone modules (either wholly new or extracted from one of the twelve proposed modules)?

2. The course will likely be a mix of on-demand content and instructor-based lectures, with reading assignments and tests of knowledge throughout the course. Because we are trying to achieve the optimal mix, please assign a weight to each element below from 1 to 5, with 1 being "I don't find this element useful at all" and 5 being "I find this element extremely important."

	1	2	3	4	5
Lesson-Based Video Modules	○	○	○	○	○
Reading and homework assignments	○	○	○	○	○
Quizzes and tests	○	○	○	○	○
Course projects (such as research papers)	○	○	○	○	○
Hands-on instruction	○	○	○	○	○
One-on-one time with the instructor	○	○	○	○	○
Moderated peer discussions	○	○	○	○	○

What other kinds of training methods do you think that power quality training should include?

3. Writing assignments can reveal whether a student grasps the nuance of the technical content of the course, although they may also significantly increase the student's outlay of time outside the "classroom," as well as the instructor's time grading them. Should writing assignments, such as technical essays, be combined with tests and quizzes to gauge student comprehension and recall?

○ Yes

○ No

Please include the rationale for your answer.

4. Awarding a certificate of completion to a student requires measuring how well the student learned the course content. How should the performance of students be evaluated during the course? Please select one.

- ○ Quantitative through grading quizzes and tests.
- ○ Qualitative through grading writing projects and participation in discussions.
- ○ Both of the above.
- ◉ Pass/fail to achieve the certificate.

What other kinds of progress evaluations seem appropriate for the proposed PQCT?

5. Should the PQCT employ group assignments, such as peer review and group homework?

- ○ Yes
- ○ No

Please list any group activities that seem appropriate for the proposed PQCT.

6. Many people learn primarily through vision. To facilitate this mode of learning, instructional videos can include the instructor handling real-world instruments (analyzers, CTs, PTs, PQ monitors, and so on), transmission and distribution components (circuit interrupters, reclosers, regulators, and so on), and industrial equipment (PLCs, relays, CVTs, and so on) while wearing a VR headset (such as RealWear) to enhance the student's point of view. However, this approach may significantly increase the cost of producing instructional videos and therefore increase the price of the course to students. Please assign a weight from 1 to 5 to how important such a virtual point of view would be to the proposed PQCT, with 1 being "not important at all" and 5 being "extremely important."

1	2	3	4	5
○	○	○	○	○

Please list any other visual methods of instruction that you would like to see included in this course

7. For you and your staff, what is the real-world application of achieving a certificate in power quality training? For example, how would people apply what they learn to their jobs? How important would completing such a course be to not only improving work performance but also advancing careers within your utility?

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B
VERBATIM RESPONSES FROM SURVEY

1. What other subjects would you like to see included in basic PQ training as standalone modules (either wholly new or extracted from one of the twelve proposed modules)?

- Ferroresonance, subharmonics, interharmonics, high frequency noise, converters and their effect on frequency spectrum in power system, effects of harmonics on revenue meters, machines, transformers, and other equipment, induced voltages and currents (stray voltage) and grounding (example swimming pools), lightning mitigation methods.
- Understanding and managing PQ effects of small scale (up to say 10 kW) LV solar DG. PQ effects of larger scale (MW to 10s of MW) solar and wind DG, connected at MV levels. PQ effects of inverter based battery charging, EVs and the like.
- Electrical measurements - Volts, Amps, Watts, vars, etc. (thinking basics like tools and how they measure: RMS, peak/sqrt(2), fundamental, average, DC offsets); Electrical Safety (MAD, Arc Flash, PPE, equipment voltage/current limits,)
- Addressing stray voltage, both routine such as swimming poles and more detailed. This is a topic often turned over to PQ professionals for resolution and of vital importance.
- Under the PQ mitigation for the grid section, I assume this would address both distribution and transmission voltages. For the understanding resonance, I presently have a need to mitigate resonance, so I would like to understand a computer program (possibly the harmonics module of CYME) to be able to have our distribution engineers identify and mitigate potential problems.
- PQ Reports for Customers Performing Customer Audits
- Voltage Unbalance, Voltage Levels and Regulation (ANSI C84.1), Grounding & Bonding, Stray & Contact Voltage and Elevated Neutral-to-Earth Voltage, Radiated Emissions (RFI, Electric & Magnetic Fields), PQ and IT (PQ Monitoring Systems: Configuration, Data Retrieval, Data Storage, Visualizations, Automation of Analytics and Reporting).
- Grounding, Future grid impacts, some process and controls survey
- A course on grounding and stray voltage would be helpful. Also a topic on induced voltage (from transmission lines to rail or buried pipelines). Another helpful topic would be “How to find and vet new equipment” I find myself spending hours trying to find equipment that fits our power quality needs.
- Discussion on pending PQ issues and higher concentrations of renewables and DER are installed.

2. What other kinds of training methods do you think that power quality training should include?

- I've found that anecdotal experience can be the best trainer, which is why I would favor peer discussions i.e. telling stories, and also hands-on instruction.
- PQ Lab and Field exercises, including writing reports/analysis of results.

- As much self paced (pre-recorded) content as possible. It is very difficult to consistently block time out of the day, but much easier to be able to grab a class and listen to it as schedules permit.
- Field-based monitor installations.
- Field and Lab Exercises, Live Webinars, In-Person Training, Provide an On-Line Log of Credits Earned / Courses Taken
- A course discussion board for students to interact - ask questions give answers and instructor answers can be posted.
- On going video updates on new topics and issues found in field from the certified PQ Engineers.
- Important to make the time required useful and worth doing.

3. Please include the rationale for your answer to: Should writing assignments, such as technical essays, be combined with tests and quizzes to gauge student comprehension and recall?

- If the student were seeking some type of certification or degree, then I would agree this would be needed. If the course is more for the professional to increase knowledge to help in their current job function then I don't see this requirement to be largely beneficial since there is no degree/certificate attesting to the students understanding.
- I could go either way with this question. As long as the tests and quizzes are adequate, i am not certain writing technical essays would be worth the additional time required.
- Unnecessary use of student and instructor time.
- Writing ensures understanding
- We often are called upon to deliver the results of our research so we should be able to communicate the findings in not just written but oral communication so that the recipient can understand it in a lay-mans terms
- Written explanation provides greater insights of the students understanding of the subject. The student will need to be able to explain such subjects to others including those without technical proficiency in the general public and customers.
- I'm on the fence with this one. I guess if push came to shove I'd opt out. Not that I don't see the value, just a inclination.
- With research papers, there can be a tendency to spend more time on the 'quality' of one's writing than deepening one's technical understanding of a topic.
- Hotline topics should be a substitute for the writing assignment. Otherwise it is a good idea as long as it is well defined.
- Not a college course but training for industry professionals. Getting a completion certificate is not the same a college degree

4. What other kinds of progress evaluations seem appropriate for the proposed PQCT?

- Consider presentations on PQ topics and/or cases to be presented to instructor and course participants (in lieu of research papers)

- Quantitative through grading quizzes and tests, however, participation should also be a consideration.
- Completion of Field and Lab exercises
- Quizzes and tests that prepare the student for a final exam seem to be a tried and true model and consistent with the professional standards we generally hold in high regard.
- A test should be available in place of the writing project to test a persons knowledge on specific subjects.
- Again, this is not a college course but industry training. Treat it that way.

5. Please list any group activities that seem appropriate for the proposed PQCT.

- If you could use a facility like Lenox and stage a PQ problem, within the time frame of the course, that might work. Otherwise, it's hard enough getting time to take training, never mind getting an extracurricular group together that's possibly in different time zones.
- Pertinent research and white paper topic - perhaps as a capstone?
- Lab and field work exercises, tours, etc. Can you really get this certification without ever taking a measurement or inspecting a customer site?
- PQ Inquiry Case Studies
- Lab Demos
- When EPRI performs PQ field assessments, include utility employees in the assessments so that they gain first-hand real-world experience. Students could also accompany seasoned PQ staff within the utility to gain such experience from field assignments.
- Again, on the fence here. I don't think it's a must but, I suppose it could be valuable exercise to carve out a reasonably sized project for a group to collaborate in.
- There's clearly benefits of group work outside the classroom. With busy work schedules and different time zones however, I'm concerned it may be difficult to sufficiently collaborate with other members of the course.
- Assign group activities for each utility to work as a team to accomplish.
- Some limited group work is useful but not as a course requirement

6. Please list any other visual methods of instruction that you would like to see included in this course.

- I agree with the sentiment (as I am a visual learner), I'm just not sure on the value of virtual learning.
- Using special technology like virtual headsets will be hard to achieve. I think we should keep it to standard two way video and audio, real time and recordings as needed.
- An employee with enough experience to participate in a course of this nature should already be familiar with the equipment and instruments.
- I have found participating in VR events make me sea-sick (thank you Jason Anderson).
- Video would be acceptable, but VR would be ideal.
- I best learn by seeing and doing.

- Customer equipment is foreign to utility personnel. Students need to see what they will be addressing at the customer's facility.
- this could be a home based monitoring give them a project and have them record it and share results with peer group or instructor.
- I suppose it depends on exactly what the lesson is focused on for including the real wear. I don't see value from a show and tell perspective but, if your focus is on for example how to perform an audit in a manufacturing process it can be useful.
- Whiteboard/blackboard instructor led class. Point-of-view filming (bodycam?) may be a more affordable substitute for VR.
- It would be good to revisit this idea in a few years but the current technology is not to a point where the cost would be justified vs just using a normal camera or drone.
- Again, use what is needed to accomplish the goal of the training, not an opportunity to have EPRI develop a video game.

7. For you and your staff, what is the real-world application of achieving a certificate in power quality training? For example, how would people apply what they learn to their jobs? How important would completing such a course be to not only improving work performance but also advancing careers within your utility?

- The main thing is that the people that need the knowledge have it so they can apply it when needed.
- For someone representing a utility, a certificate gives me some "street cred", when talking to customers. For an electrical utility engineer, as Bill says, our product is quality power/voltage. When you're not doing that, someone needs to be able to figure it out!
- This could become part of the onboarding package for new hires to the PQ Team. The idea is to lay a strong foundation in education that is too specific/nuanced for university coursework and does not otherwise exist in the marketplace. Further, many engineers within our agency but not necessarily on the PQ team are required to received some PQ shadowing/mentoring as part of their progression plan. This course could also serve as a solution for that, particularly in a virtual environment where shadowing is more of a challenge.
- Having a certificate would be a useful demarcation point for job applicants wanting to work in this area.
- Main thing would be knowledge transfer, EPRI facilitating that rather than needing to do that internally with limited resources (time, personnel) to properly handle that prior to employee retirements and transfers. We do not have a PQ group, but various engineering groups (relaying, planning, substation O&M) find themselves involved in resolving PQ issues for member cooperatives and end use customers on a somewhat regular basis.
- Does the act of performing an Power Quality investigation become the practice of engineering, and require the investigation be performed by our under the direct supervision of a Professional Engineer? The Ohio Law would seem to indicate such in 4733.01(E), (E) "The practice of engineering" includes any professional service, such as consultation, investigation, evaluation, planning, design, or inspection of construction or operation for the purpose of assuring compliance with drawings or specifications in connection with any public or privately owned public utilities, structures, buildings, machines, equipment,

processes, works, or projects in the proper rendering of which the qualifications of section 4733.11 of the Revised Code are required to protect the public welfare or to safeguard life, health, or property.

- Completing a course of this nature would directly benefit the staff and company in strengthening their ability to serve our customers and understand our business from a technical perspective.
- Relieving a certificate would be of minimal impact. It may possibly matter for the 5 or 6 PQ engineers in the organization to set 1 apart from the group during interview, otherwise a certificate wouldn't matter and the course would be for personal improvement.
- AEP has grown our Quality of Service (PQ) department. For my staff, this would be a great training method. A shortened version of training might also be beneficial, for example for our Distribution engineers and to a lesser extent our Customer service engineers, account managers and representatives.
- Minimal impact because the customers do not require a certification when they request assistance from us.
- by upskilling our technicians we ensure our customers receive the best possible service from the utilities and have an SME to go to when equipment on their side mis-operates
- there are different potential areas - customer claims, grid planning and development, gird maitenance
- PQ teams within the utility have traditionally been small in number. Many PQ experts across the utility industry are retiring with limited natural succession opportunities. The PQCT will fill a gap in training for succession planning.
- Ultimately, while it's always fun to learn new things, unless the student plans to be a practitioner there's not much use. As a practitioner though, this course should be very useful in utilizing/developing PQ engineer skills and as an industry credential.
- To foster a strong competency in identifying, resolving, and mitigating PQ issues; and to in-turn share that knowledge with other engineers and technicians.
- Being able to market to our customers that we go through power quality training will show a level of in-depth training that will help them trust that we can solve their power problem. At some utilities you need a PE or CEM to move up to a principle role and having this would be a good substitute for those of us with technology degrees.
- This is important for some of our staff but not all. Completing this course is not a career game changer or going to allow them to receive a higher paycheck.

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