EPIC Final Report

Program	Electric Program Investment Charge (EPIC)
Administrator	San Diego Gas & Electric Company
Project Number	EPIC-3, Project 4
Project Name	Safety Training Simulators with Augmented Visualization
Module Name	Module 2, Virtual Reality Training Simulator for Personal Protective Grounding/Equal Potential Zones on the Electric Distribution Underground System
Date	December 31, 2021

Attribution

This comprehensive final report documents the work done in Electric Program Investment Charge (EPIC) in Project 4 of the portion of EPIC funds administered by SDG&E in the third EPIC cycle (EPIC-3). The project team that contributed to the project definition, execution, and reporting included the following individuals, listed alphabetically by last name:

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Executive Summary

The objective of SDG&E's EPIC-3 Project 4 on "Safety Training Simulators with Augmented Visualization" was to demonstrate and evaluate augmented reality applications for field focused design, operations, asset monitoring, and management solutions. It demonstrated the ability of the latest simulator technologies to train utility industry personnel on safety-related issues, including electric potential zones and grounding techniques associated with construction work practices. The project was divided into two modules. This project covers the second module which was to conduct a pre-commercial demonstration of a field worker safety training system using virtual reality technology to immerse students more thoroughly in safety procedures related to work with de-energized underground distribution lines.

- Module 2 of this project explored virtual reality applications for field focused design, operations, and asset monitoring and management solutions, and how Virtual Reality tools can be utilized to demonstrate its ability to train utility industry personnel on safety related issues, such as Equal Potential Zones (EPZ) and grounding techniques associated with current construction work practices and provide rich contextual information at the point of work.

The following were demonstrated in Module 2:

- <u>A Virtual Reality for each scenario</u>
  Demonstrate the new training simulator's ability to guide one or more students using wireless Virtual Reality (VR) goggles with virtual hands through five different scenarios.
- <u>A two-dimensional training simulator for each scenario</u>
  Demonstrate how students are able to complete the training in a two-dimensional environment.
- <u>A learning management system (LMS) for each scenario</u>
  Demonstrate the simulator's ability to assist the student through the five scenarios.

The demonstration of VR training methods showed improvement in almost every criterion assessed as a success factor including information retention, situational awareness, level of engagement, content clarity, and participant's level of confidence

Along with confirmed success factors discussed above, a few challenges were noted.

- Initial increase in training costs
- Employee learning curve to adapt to new technology
- Employees with little or no previous experience with VR or similar technologies

Overall, the system demonstrates an effective and improved training method over traditional training methods that utilize only text and training videos. The VR training comes a step closer to real time hands-on experience, without the associated risks, enabling the trainee to learn the procedures in a safer environment. As a result, the participants showed an increased level of confidence, making VR training a very effective approach.

This EPIC project has ended. It is recommended that the VR training method be pursued commercially for its effectiveness in training employees from the trade on grounding and EPZ procedures unique to electric underground distribution. It is recommended that follow-up work be pursued to establish a path to commercialization. The appropriate internal SDG&E stakeholder group should be given the lead responsibility for managing the commercialization process.

Logical "next steps" towards commercialization would include:

- Setting up a permanent resource team to accomplish commercialization
- Arranging funds for commercial adoption and on-going maintenance of commercial operations
- Developing a commercialization plan

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List of Acronyms

Acronym	Acronym Description
AR	Augmented Reality
CPUC	California Public Utilities Commission
EPIC	Electric Program Investment Charge
EPZ	Equal Potential Zone, or Equipotential Zones
LMS	Learning Management System
PPG	Personal Protective Grounding
SDG&E	San Diego Gas & Electric
UG	Underground
VR	Virtual Reality

1.0 Project Objectives

The objective of SDG&E's EPIC-3 Project 4 on "Safety Training Simulators with Augmented Visualization" was to demonstrate and evaluate augmented reality applications for field focused design, operations, asset monitoring, and management solutions. It demonstrated the ability of the latest simulator technologies to train utility industry personnel on safety-related issues, including electric potential zones and grounding techniques associated with construction work practices. The project was divided into two modules. This project covers the second module which was to conduct a pre-commercial demonstration of a field worker safety training system using virtual reality technology to immerse students more thoroughly in safety procedures related to work with de-energized underground distribution lines.

Module 2 of this project explored virtual reality applications for field focused design, operations, and asset monitoring and management solutions, and how Virtual Reality tools can be utilized to demonstrate its ability to train utility industry personnel on safety related issues, such as Equal Potential Zones (EPZ) and grounding techniques associated with current construction work practices and provide rich contextual information at the point of work.

2.0 Issues and Policies Addressed

The primary issue addressed for this project was to explore more effective training methodologies using new simulation technologies that use augmented or virtual reality and quantify their effect on parameters like public and personnel safety, training time and associated costs, field workforce readiness, and associated benefits in managing an electrical distribution underground system.

State, and specifically, CPUC policy towards an increased role in promoting safety for utility operations has led to a greater emphasis for utility leadership to focus on this area. For contracted as well as regular employee work, utilities are expected to perform effective oversight on all work practices. Due to the nature of the work, many utility workers interact daily with scenarios that, if handled improperly, can lead to life-changing, or life-ending, outcomes. The application of contemporary technology to promote the readiness of these workers supports state policy. Opportunities to add new technologies that may enhance contemporary practices are explored through projects such as this one.

3.0 Project Focus

The focus of this project is to perform a pre-commercial demonstration of augmented reality applications for field-focused design, operations, and asset monitoring and management solutions. The project will demonstrate the ability of the latest simulator technologies to train utility industry personnel on safety-related issues, such as equal potential zones (EPZ) and grounding techniques associated with construction work practices. The demonstration will include utilization of augmented reality tools to visualize and provide rich contextual information within the delivery of the training.

4.0 Project Scope Summary

The scope of this module was to demonstrate a VR pre-commercial training stimulator for Personal Protective Grounding/ Equal Potential Zone (PPG/EPZ) on the electric distribution underground (UG) system. This new training will be used for students initial and/or refresher compliance training to understanding of the procedures for PPG/EPZ. The case for prospective commercial adoption of the training was examined. This comprehensive final report provides documentation of the module approach, demonstration results, final benefits estimate, value proposition, and recommendations regarding commercial adoption.

This training simulator guides one or more students using VR goggles through five different EPZ and grounding techniques. These five different scenarios go from simple to very complex EPZ and grounding techniques. The simulator would be able to assist students through the five following scenarios:

- Replace an elbow in a handhole with jacketed cable.
- Replace a run of cable between two handholes with jacketed cable.
- Replace a “T” in a handhole with unjacketed and jacketed cable.
- Replace a live front piece of equipment to a dead front with unjacketed and jacketed cable.
- Change a four-way pad mount switch with jacketed cable

5.0 Approach for Project Module 2 Activity

The approach for this project included the following tasks, designed to demonstrate a functioning precommercial training simulator for utilizing PPG/EPZ methods on the electric distribution underground (UG) system.

Task 1 - Initiation of Project Plan

- Identification of stakeholders
- Project kick-off, development of project plan, resource requirements, and formation of internal project team

Task 2 - Development of Project Requirements

- Fact finding from literature or other programs
- Baselining current situation and practices

Task 3 - Development of Funding Base and Collaborative Funding or Partner Arrangements

- Examine opportunities for partnering and cost sharing to enable more work to be done in simulation and visualization development.

Task 4 - Contractor Procurement

- Select a qualified contractor(s) to assist with engineering support services related to the project.

Task 5 - Site Selection and Arrangement for the Safety Training Simulation and Visualization Equipment (Hardware and Software)

- Select a preferred site

Task 6 - Preparation of Use Cases and/or Test Plan for Demonstration

- Preparation of Use Case(s) to define the content of the demonstration and to ensure all benefits will be measured in the project.

Task 7 - Development of Test Set-up and Safety Training Simulation/Visualization Modeling Capability Support

- Testing and measurement for scenarios in use cases
- Procure equipment and software

Task 8 - Execution of Demonstration

- Perform the demonstration of the VR technology
- Perform trial run of the training scenarios

Task 9 – Analysis of Data and Other Demonstration

- Assessment of effectiveness of the VR technology and training

Task 10 - Development of Conclusions and Recommendations

- Use the results of the data analysis task to update the initial benefits analysis and to formulate key findings, conclusions, and recommendations for the project. This material will be integrated into the comprehensive final report for the project.
- Determine the relative value proposition for each use case.

Task 11 - Preparation and Implementation of Tech Transfer Program for Deployment Site

- Develop, prepare, and implement a tech transfer plan
- Identify the process for transferring project results into practical use by SDG&E, as well as by other potential users.
- The tech transfer plan should be consistent with the recommendations made regarding which use case should and should not be pursued commercially.

Task 12 - Perform Interim Project Reporting

- Perform required interim reporting activities, throughout the life of the project.

Task 13 – Disposition Plan for Equipment and Software

- Define and implement a disposition plan for equipment and software used in the project

Task 14 - Preparation of the Comprehensive Final Report

- A comprehensive final report shall be prepared that captures the objective, initial benefits analysis and value proposition, description of the metrics and use cases, demonstration results, data analysis, final benefits estimate and value proposition, conclusions, and recommendations regarding commercial adoption.
- Prepare a draft report for review and a revised final version of the comprehensive final report for Module 2.

5.1 Baseline Studies/Fact Finding

5.1.1 Initial Benefit Estimate and Value Proposition

The goal of Module 2 was to demonstrate use of virtual-reality visualization tools to aid in training field employees in safe practices for working situations where there is the possibility of unexpected hazardous levels of electric potential. The case for prospective commercial adoption of the training will be examined. The following were the identified initial project benefits and value proposition:

Safety to SDG&E's Personnel

- With the VR simulator, SDG&E would be able to provide initial and refresher training to more employees on the proper procedures of doing PPG/EPZ on distribution UG.

Safety to the Public

- With the VR training, SDG&E would be able to restore power to the customer more quickly and safely and to reduce public exposure to a potentially energized system, especially first responders.

Risk Reduction

- The VR training would help protect employees from hazardous potentials caused by line induction and/or non-utility generation sites (e.g., photovoltaic systems, wind turbines).

Reduced Cost

- The enhancement of training would help reduce outage times and associated costs, due to the increased skill level of employees.

Value Propositions – SDG&E Electric Operations

Employee training is a constant, critical task that must be executed efficiently and effectively. Employee, and by extension, public safety is a function of how effective these programs are in establishing and maintaining good work habits and conservative approaches to inherently hazardous tasks. Significant injury, loss of life and property can result otherwise.

Value Propositions – State Initiatives

The core duty of the utilities is the safe provisioning of electric service. In the fulfillment of this responsibility, it is imperative that operating utilities strive to protect the public and all employees from the hazards of providing electric energy for beneficial use. Enhancing the ability of operating utilities to keep employee competence and readiness at the highest possible level supports the state's goals related to safety outcomes, by all measures.

Safety is an element of the overall EPIC framework and is specifically stated as an element in the state's Public Utility Code 8360.

Further, promoting the readiness of utility workers as they interact with high-risk electrical hazard scenarios, helps to also ensure the safety of the SDG&E employees.

5.1.2 Initial Selection of Metrics

The following were identified as initial project metrics for measuring success and benefits of the demonstration.

Benefit 1 – Increase in worker effectiveness attributable to the training: The VR training can be a more effective tool in terms of clarity and use of the content, making it more effective compared to traditional methods using presentations and videos only.

a. Benefit description: The VR training displays a more engaging experience for the participants by simulating the real field scenario and therefore makes it easier to visualize, understand and memorize the training instructions. The student experience is far more participatory and immersive, rather than passive.

b. Desired target: Demonstrates increased information retention and increased situational awareness and confidence level by the participants.

Benefit 2 – Safety to SDG&E's Personnel: The VR training provides increased safety to SDG&E's personnel during training.

a. Benefit description: The VR training allows participants to practice the scenarios safely, avoiding exposure to potential hazards.

b. Desired target: Significantly reduces incidents and injuries.

Benefit 3 – Increased number of trained personnel available

a. Benefit description: Increased understanding of PPG/EPZ processes and personnel's ability to perform them in the field to achieve associated benefits like increased jobsite safety and reduction in operation costs.

b. Desired target: Increased number of personnel competent in PPG/EPZ procedures.

5.2 Description of Pre-Commercial Demonstration

5.2.1 Location

The demonstration was conducted at the SDG&E Skills Training Center, in San Diego, California.

5.2.2 Use Cases

Table 1 describes the use cases and the five selected scenarios for testing of the VR and training of EPZ work methods.

Table 1: Use Case Scenarios

Scenario	Use Case	Description
1	Replacing Elbow	The trainees change out a bad load break elbow. To complete this operation, the trainees performed work at two above ground structures using EPZ work methods. Included were a fuse cabinet and dead front terminator. All switching, tagging and holds had been completed. The primary focus was to establish and maintain an EPZ. The last two sentences can be considered common to the other four use cases below and will not be repeated.
2	Replacing Cable Run	The trainees replace a bad run of cable that goes from an above ground structure to a hand hole using EPZ work methods. The trainee began at the switch cabinet where the bad cable originated.
3	Replacing a T connector	Trainees replace a bad 600-amp T connector, which was located inside of a handhole. The trainees worked with both jacketed and unjacketed cable. Using EPZ work methods they performed work within this structure, another handhole and switch cabinet.
4	Live Front to Dead Front Equipment Replacement	Trainees replace a live front terminator containing both jacketed and unjacketed cable with a dead front terminator. Using EPZ work methods trainees performed work at the terminator and within two handhole structures.

Scenario	Use Case	Description
5	Changing a Switch	Trainees change out a four-way pad mounted switch, using EPZ work methods. The work physically occurred at the surface mounted switch, and within two adjacent handholes.

5.2.3 Equipment Requirements

The equipment and software used in the VR Safety Training Simulators is outlined in Table 2.

Table 2: Equipment and Software Requirement

Equipment	Requirement
VR Headsets	Oculus Quest (with developer mode enabled) Facebook (META) account to load software onto headset. Software will work on Oculus Headsets with memory storage, or VR software can run on a PC or Laptop and connect to Oculus or other headsets via Link cable or by streaming using Wi-Fi. A wireless router that supports 5 Ghz operation is required.
Computer	High-end gaming PC or Laptop with discrete graphics card. When running VR, Video card needs to have at least 6GB Video memory.
Virtual Reality Program	Loading of VR software requires an account login, mobile app for mobile device(s) and a PC or Laptop with a software loaded for copying software to VR Headset.

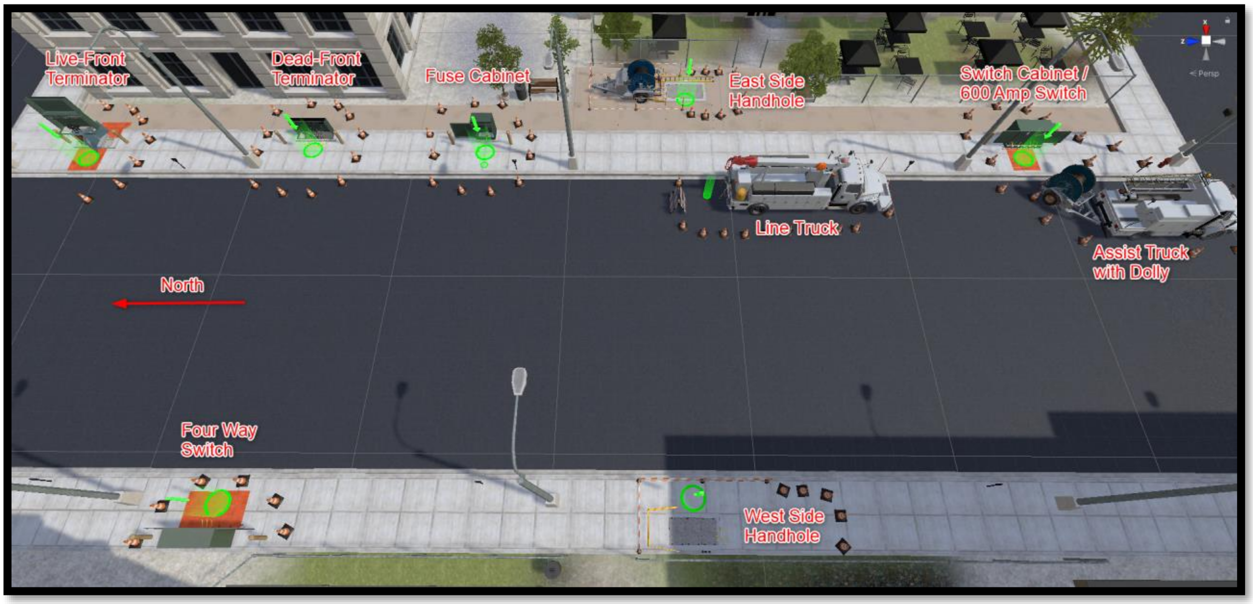
5.2.4 Supporting SDG&E Infrastructure and Data Requirements

SDG&E's infrastructure supported connectivity with above software and hardware using existing PC/Laptops. VR headsets were obtained separately as required by SDG&E and use of the Learning Management System (LMS) was provided by the selected vendor.

5.2.5 Execution of Demonstrations

The training simulator is designed to guide one or more students in using VR googles through five different EPZ and grounding techniques. These five different scenarios go from simple to very complex. The simulator can assist students through the five scenarios, test them on each scenario and retain records that the participant completed the training. The virtual application layout used for five different EPZ and grounding scenarios is shown in Figure 1.

Figure 1: Virtual Application Layout



The five different scenarios are:

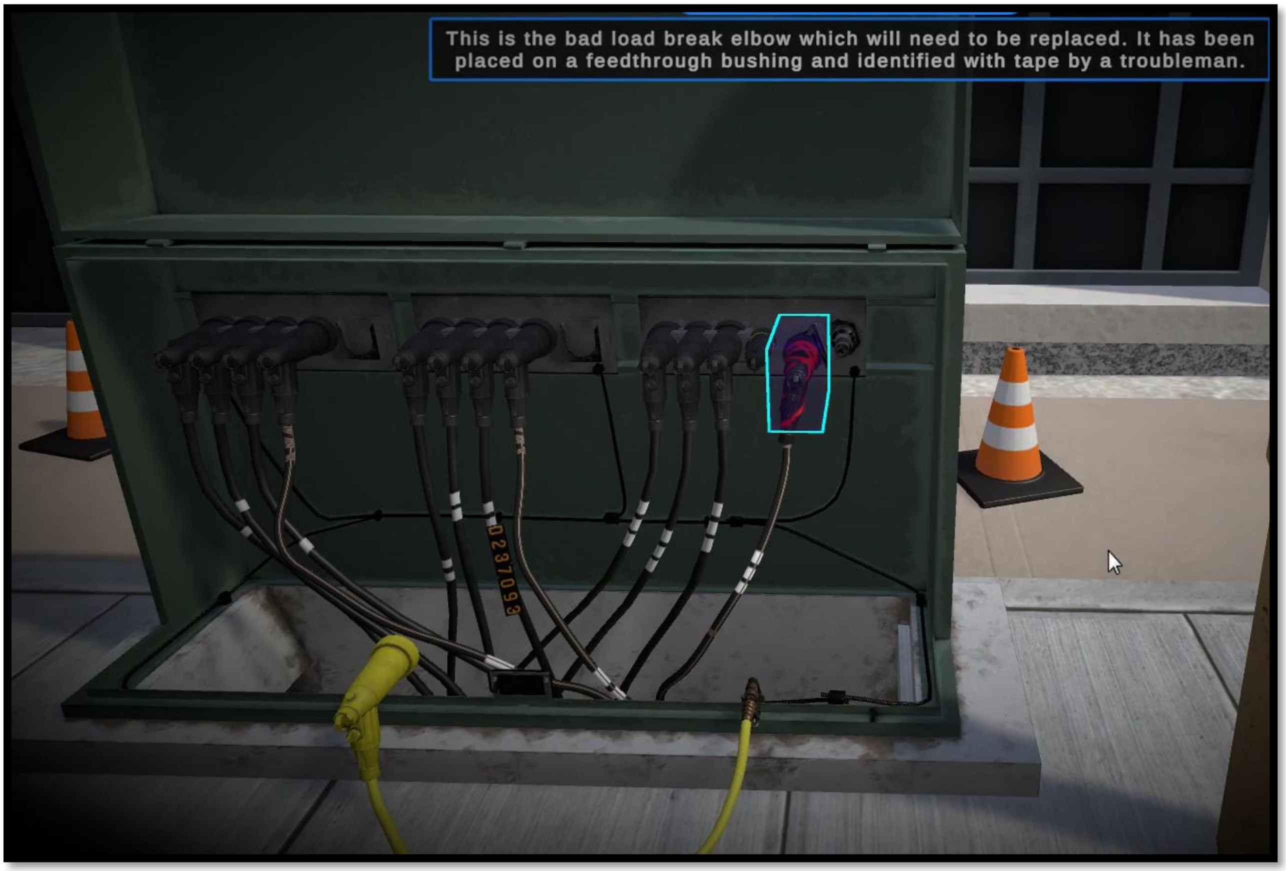
- Replace an elbow in a handhole with jacketed cable.
- Replace a run of cable between a handhole and a switch.
- Replace a “T” connector in a handhole that connects to unjacketed and jacketed cables.
- Replace a live front piece of equipment to a dead front that connects to unjacketed and jacketed cables.
- Change a four-way pad mount switch that is connected to jacketed cables

5.2.6 Use Case Execution

During the simulation, the participants were required to navigate the various structures and click on interactive objects.

In this scenario trainees changed out a faulty load break elbow, shown in Figure 2. To complete this operation, the participant’s performed work on two above ground structures using EPZ work methods. Included were the fuse cabinet and dead front terminator. All switching, tagging and holds had been completed. The primary focus was to establish and maintain an EPZ.

Figure 2: Faulty Load Break Elbow



During the simulation, the participants were required to cross the street to investigate various structures. Whenever they crossed the street, it was imperative that the participants check for traffic and follow best practices related to road safety. It showed a list of steps which needed to be completed for the current scenario. The operation order could be collapsed or expanded by clicking the "operation order" button. Green check marks would appear beside those steps which had been completed correctly.

Step 1. Identify faulty load break elbow

Step 2. Test de-energized and ground cable inside of fuse cabinet

Step 3. Test de-energized and bump ground cable inside of dead-front terminator

Step 4. Create EPZ in structure with faulty elbow

Step 5. Replace the faulty elbow

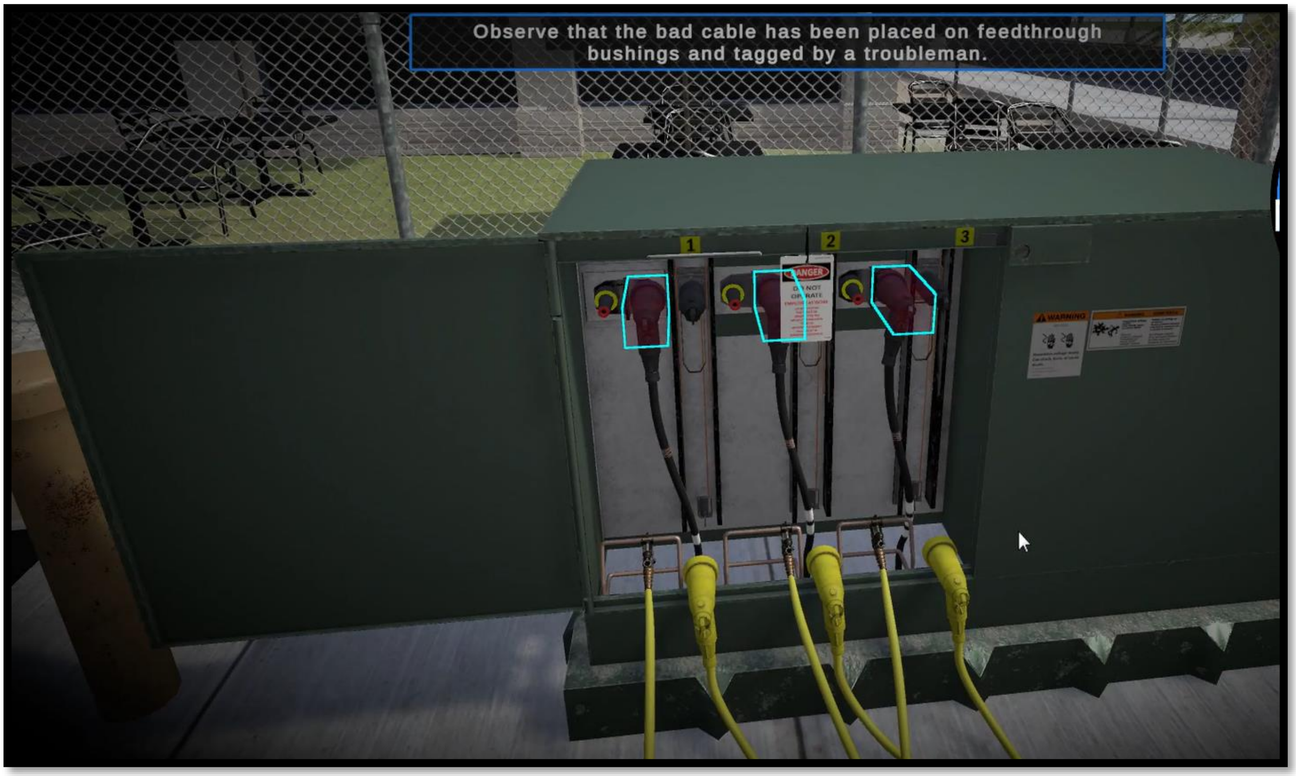
Step 6. Re-energize the fuse cabinet

Step 7. Restore service inside the dead-front terminator

Use Case/Scenario 2 – Replacing Cable Run

In this scenario, the participant's replaced a faulty run of cable, shown in Figure 3. It goes from an above ground structure to a handhole using EPZ work methods. The work began at the switch cabinet where the faulty cable originated. All switching, tagging and holds had been completed. The primary focus was to establish and maintain an EPZ. Operation order below list the steps which were required for this scenario.

Figure 3: Faulty Run of Cable



Step 1. Identify faulty run of cable

Step 2. Test de-energized and ground cable inside of switch cabinet

Step 3. Test de-energized and ground cable inside of handhole

Step 4. Create EPZ in handhole

Step 5. Descend into handhole

Step 6. Replace faulty cable

Step 7. Re-energize the switch cabinet

Step 8. Re-energize the handhole

Use Case/Scenario 3 – Replacing a T Connector

In this scenario, the participants replaced a failed 600-amp T Connector, shown in Figure 4. It was located inside of a handhole. The participants had to work with both jacketed and unjacketed cable. Using EPZ work methods the participant's performed work within this structure, another handhole and a switch cabinet. All switching, tagging and holds had been completed. The focus was to establish and maintain an EPZ. Operation order below lists below the steps which are required for this scenario.

Figure 4: Failed 600-AMP T Connector

Step 1. Identify T to be replaced

Step 2. Test de-energized and ground cable inside of switch cabinet

Step 3. Test de-energized and ground cable inside of handhole

Step 4. Test de-energized and ground cable inside of handhole with T to be replaced

Step 5. Create EPZ in handhole

Step 6. Descend into handhole

Step 7. Perform T body replacement

Step 8. Complete work at east side handhole

Step 9. Complete work at west side handhole

Step 10. Restore service inside switch cabinet

Use Case/Scenario 4 – Live Front to Dead Front Equipment Replacement

In this scenario, the participants replaced a live front terminator containing both jacketed and unjacketed cable, to a dead front terminator. A picture of the live front equipment that needed to be replaced, shown in Figure 5.

Figure 5: Live Front Equipment to be replaced

Using EPZ work methods the Participants performed work within the terminator and two handhole structures. All switching, tagging and holds had been completed. The primary focus was to establish and maintain an EPZ. Operation order below lists the steps which were required for the scenario.

Step 1. Identify Live Front Equipment

Step 2. Test de-energized and ground cable inside of east side handhole

Step 3. Test de-energized and ground cable inside of west side handhole

Step 4. Test de-energized and ground cables inside of live front terminator

Step 5. Remove cabinet and create EPZ

Step 6. Splice cable tails

Step 7. Install dead-front cabinet

Step 8. Prepare dead front terminator for energization

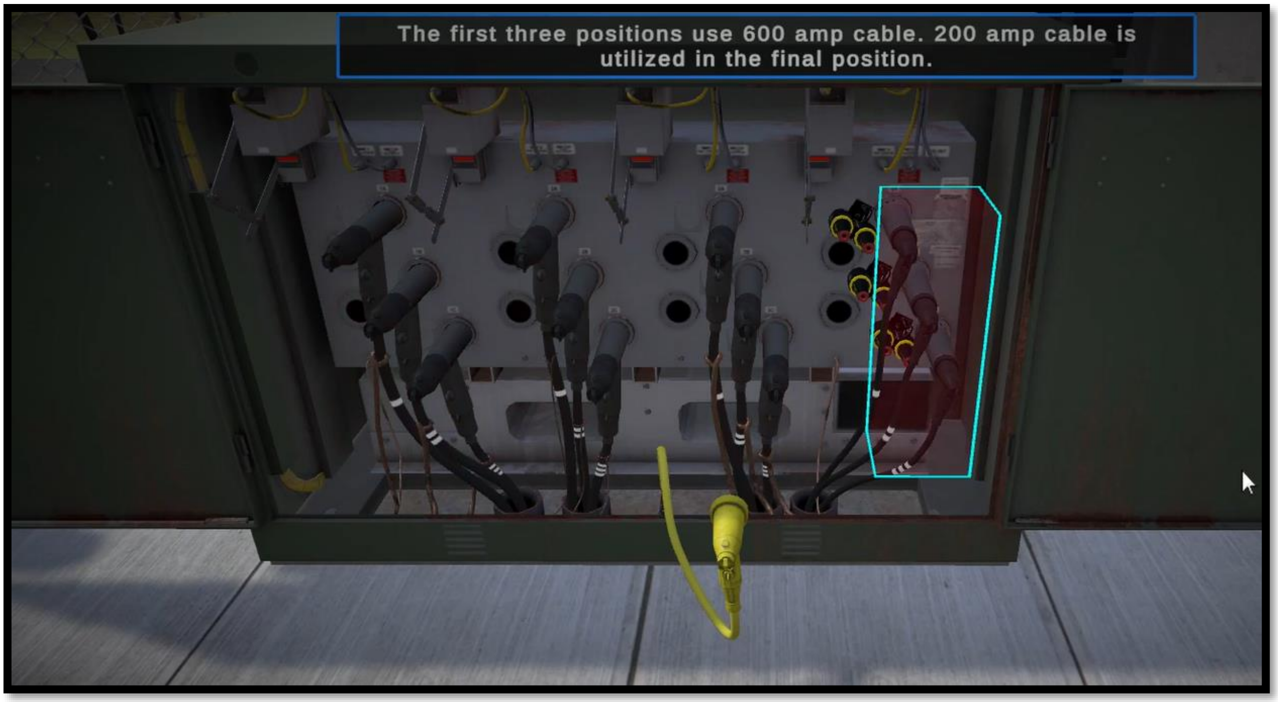
Step 9. Complete work at west side handhole

Step 10. Complete work at east side handhole and restore service

<u>Use Case/Scenario 5 – Changing a Switch</u>

In this scenario, the participant's changed out a four-way pad mounted switch, shown in Figure 6, using EPZ work methods. All switching, tagging, and holds had been completed. The primary focus was to establish and maintain an EPZ. Operation order below lists the steps which were required for this scenario.

Figure 6: Four-way switch



Step 1. Identify four-way switch

Step 2. Test de-energized and ground cable inside of 600-amp switch

Step 3. Test de-energized and ground cable inside of east side handhole

Step 4. Test de-energized and ground cable inside of west side handhole

Step 5. Test de-energized and ground cable inside of dead-front terminator

Step 6. Test and bump ground all positions inside four-way switch

Step 7. Create EPZ around four-way switch

Step 8. Pull away T bodies

Step 9. Pull out feedthrough bushings

Step 10. Change switch

Step 11. Install feedthrough bushings

Step 12. Install T bodies

Step 13. Take 200-amp elbows off feedthroughs

Step 14. Complete work at four-way switch

Step 15. Prepare dead front terminator for energization

Step 16. Remove grounds at west side handhole

Step 17. Remove grounds at east side handhole and restore service at 600-amp switch

5.2.7 Data Acquisition

The participants were asked to provide their feedback about the new training method using VR as compared to traditional training. The participants feedback included measurable success factors such as level of engagement, ease of use, clarity of training content, participant's confidence level, and overall training effectiveness along with safety and risk were assessed. The participant survey template can be found in Appendix A.

All the survey success factors were measured and assessed on a scale of 1 to 5 with the highest success rating being 5, significantly increased and the lowest rating being 1, significantly reduced. The survey scale ratings were as follows:

<u>Participant Survey Rating Scale</u>

1 - Significantly Reduced

2 - Visibly Reduced

3 - No Change

4 - Visibly Increased

5 - Significantly Increased

5.3 Data Analysis

A total of seven success factors were assessed to evaluate and compare VR training with Traditional method. Data analysis results from participant surveys of the VR training are listed in Table 3. A copy of the survey used to collect the data can be found in Appendix A.

Table 3: Data Results

Success Factor Number	Success Factor Description	VR Training Vs Traditional Training
1	Information Retention	Significantly Increased
2	Situational Awareness	Significantly Increased
3	Level of engagement	Significantly Increased
4	Ease of use	Visibly Increased
5	Content Clarity	Significantly Increased
6	Level of confidence	Visibly Increased
7	Training effectiveness	Significantly Increased

6.0 Project Results

Assessment of VR Training over traditional method displayed improvements in multiple areas, including but not limited to, information retention, situational awareness, ease of use, level of engagement, clarity of training content, and level of confidence. The VR training was shown to be an improved training tool due to its overall effectiveness.

6.1 Results Discussion

The demonstration of VR training as reflected in Table 3 above showed improvement in every success factor criterion.

Overall, the system demonstrated an effective and improved training method over traditional method that utilized only presentations and training videos. As a result, the participants showed an increased level of confidence making VR a very effective training tool.

The adoption and learning curve for trainees that are unfamiliar or inexperienced with this type of technology may take additional resources to implement.

6.2 Updated Benefits Analysis

The Module 2 demonstration results successfully verified the initial benefits identified, including effectiveness of VR technology in improving safety of personnel during training and while performing work in the field. Additional benefits include reduced operation cost, an increase in the number of trained personnel available, reduced operation cost, improved customer experience, reduced training duration, and an increase in worker effectiveness attributable to the training.

The updated benefits analysis and value proposition are as follows:

Safety to SDG&E's Personnel

- With the VR simulator, SDG&E would be able to provide initial and refresher training to more employees on the proper procedures of doing PPG/EPZ on distribution UG.

Improved Customer Experience

- With the VR training, SDG&E would be able to restore power to the customer more quickly.

Risk Reduction

- The VR training would help protect employees from hazardous potentials caused by line induction and/or non-utility generation sites (e.g., photovoltaic systems, wind turbines).

Increased number of trained personnel available

- Increased number of field workers with readiness for safe work practices.

Reduced Cost

- The PPG/EPZ procedures allow the work to be performed in a localized environment and thereby reduces power outage duration, due to the increased skill level of employees. The reduced outage duration helps SDG&E reduce the cost of system operations.

Increase in worker effectiveness attributable to the training

- The VR training can be a more effective tool in terms of clarity and use of the content, making it more effective compared to traditional method using presentations and videos only.

Reduced Training Duration

- Initial studies indicate that once the training is fully developed, and the training process becomes more efficient, the participants could take less time to complete the training. This kind of training is more participatory and immersive, and is expected to provoke more conversations, which creates a better learning environment and fosters a diversity of discussion across the student cohort groups.

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Improved Customer Experience

- The reduced outages not only help SDG&E with cost reduction of system operations, but also improve the customer experience due to superior reliability.

6.3 Commercialization Cost Estimates

To estimate commercialization cost for this type of VR training program, a planning phase is needed to better understand the commercialization process and its requirements.

There is some upfront cost for VR equipment and purchase or licensing of software, but the largest expense is likely to come from additional staff and trainers necessary to implement a sophisticated VR training platform and program. The associated VR LMS does not need to be integrated into other information technology systems and can be a standalone option; this can ease cost burdens and complications of roll out.

7.0 Findings

The demonstration was successful in all the established metrics. It determined that VR tools can be utilized to train utility industry personnel on safety related issues, such as EPZ and grounding techniques associated with current construction work practices. The tools have the ability to provide rich contextual information within the delivery of the training.

The VR training is a step closer to hands-on field experience, without the associated risks, enabling the trainee to learn the procedures in a safer environment. As a result, the participants showed an increased level of confidence, making VR training a more effective approach.

Along with the confirmed success measures for this demonstration, a few challenges were noted. Those include an initial increase in training costs for the equipment and software and the necessary personnel to develop the new training requirements, employee learning curves to be able to adapt to the new technology, and the impacts for employees with little or no previous experience with VR or similar technologies.

8.0 Conclusions

The VR training successfully performed desired functions. It showed significant improvement relative to all the criteria tested against traditional training approaches. While the project did identify some initial challenges and more evaluation towards commercialization should be done to understand additional training scenarios and definitive costs, these challenges could be addressed and may phase out during commercial adoption of this VR approach.

9.0 Tech Transfer Plan

9.1 Project Result Dissemination

The primary mechanism for dissemination of the project results is this comprehensive final report, which is filed with CPUC and posted on SDG&E's public website. Interim results have been shared in EPIC symposium, prompting education and continued interest in using a VR as a training medium. Results from this deployment can also be shared via presentations at relevant industry conferences.

9.2 Transition for Commercial Use

Recommended key next steps because of the learnings from this demonstration that could assist the transition of such a technology to a commercial use are outlined below.

Step 1 - Expansion of Training Content: Before the VR training module is commercially adopted, it is recommended to expand the VR training content library to more complex scenarios from the distribution disciplines.

Step 2 – Testing and Analysis: Perform extensive testing to identify gaps and weaknesses in the VR training experience and use the results to improve clarity and completeness of the training material.

Step 3 – Long Term Impact: The VR training program needs to be studied for its long-term impacts and benefits which could be used to make required adjustments to make it a more comprehensive training program.

Step 4 – Develop VR Training Library: Make required adjustments to the training material based on the additional testing and study results before developing a complete VR training course covering every scenario for a comprehensive training program.

Step 5 – Program Storage: Procure cyber infrastructure needed to upload the program on a secure server or locally for easy access.

Step 6 – Hardware Procurement: Planning and management of procurement, installation, and maintenance of required hardware, including periodical tech transfer as equipment achieves end of useful service life.

Step 7 – Maintenance and Hardware Upgrade Policy: Develop policies for maintenance and hardware upgrade including, but not limited to, source of procurement, hardware specification, maintenance schedule, and upgrade criteria.

Step 8 – Develop Training and Testing Policy: A clear training policy includes training content, goals, criteria, duration, and testing policy. This also includes areas of testing like situational awareness and, repair process.

Step 9 – Develop Learning Management System (LMS): A LMS is needed to help record data over a specific time. This will be used to track and analyze the effectiveness of the training, gaps in the training curriculum, number of trained personnel, refresher course due dates, and other identifiable measures used to further improve the system.

10.0 Recommendations

VR can be a very successful approach to training and provides a complex engaging environment to enhance and refresh utility personnel on safety related issues, such as EPZ and grounding techniques associated with current construction work practices.

This EPIC project has ended. It is recommended that follow-up work be pursued to establish a path to commercialization. The appropriate internal SDG&E stakeholder group should be given the lead responsibility for managing the commercialization process.

Logical "next steps" towards commercialization would include:

- Setting up a permanent resource team to accomplish commercialization
- Arranging funds for commercial adoption and on-going maintenance of commercial operations
- Developing a commercialization plan

11.0 Appendix A – Sample Survey

EPIC 3 Project 4 – Safety Training Simulators with Augmented Visualization

Module 2 – Virtual Reality Training Simulator for Personal Protective Grounding/Equal Potential Zones on the Electric Distribution Underground System

Training Effectiveness Survey

1. What is your Name?

   ____

2. What is your Age?

   ☐ <30 Years ☐ 30-40 years
   ☐ 41-50 Years ☐ >50 Years

3. What is your Gender?

   ☐ Male ☐ Female
   ☐ Custom (Please Specify) ☐ Prefer not to say

4. How many years of experience do you have with electrical systems?

   ☐ <5 Years ☐ 6-10 Year
   ☐ 10-15 Years ☐ >15 Years

5. How familiar are you with Virtual Reality Training?

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   Not Familiar Very Familiar

6. How well did this Virtual Reality simulation replicate a real field scenario?

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   Disappointing Exceptional

7. How easy to use was this Virtual Reality training system?

   ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5
   Disappointing Exceptional

8. How relevant was the training material?
   ◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
   Disappointing Exceptional
9. How well prepared do you feel for a real field scenario after this Virtual Reality training?
   ◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
   Disappointing Exceptional

10. How effective/helpful was the Virtual Reality training with information retention?
    ◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
    Disappointing Exceptional

11. How engaging was the Virtual Reality training compared to traditional video training?
    ◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
    Disappointing Exceptional

12. How would you rate the overall effectiveness of the Virtual Reality Training on a scale of 1 to 5?
    ◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
    Disappointing Exceptional

13. Do you have increased situational awareness in terms of safety after Virtual Reality training on a scale of 1 to 5?
    ◻ 1 ◻ 2 ◻ 3 ◻ 4 ◻ 5
    None Significantly more

14. How long did you take to complete the training (in hours)?
    ◻ 1hr ◻ 2hr ◻ 3hr ◻ 4hr ◻ 5hr

15. Rate the following on 1 to 5 scale where "1" is Disappointing and "5" is Exceptional:

a.	Training	◻ 1	◻ 2	◻ 3	◻ 4	◻ 5
b.	Supervision	◻ 1	◻ 2	◻ 3	◻ 4	◻ 5
c.	Guidance	◻ 1	◻ 2	◻ 3	◻ 4	◻ 5
d.	Tools	◻ 1	◻ 2	◻ 3	◻ 4	◻ 5

16. Check top three things that you liked about the Virtual Reality training:

    ◻ Instruction Clarity
    ◻ Ease of use
    ◻ Better Understanding

- ◻ Higher content retention
- ◻ Reduced training time

17. Which training method would you prefer – Traditional Video training or Virtual Reality Training?
    - ◻ Virtual Reality Training
    - ◻ Traditional Video Training

18. What was the most difficult part of Virtual Reality training?

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19. What was your favorite part of Virtual Reality training?

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20. What is one thing that can be improved?
