



Virtual reality training material

E2DRIVER H2020 project

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ABBREVIATIONS

3D: Three dimensions

AR: Augmented Reality

CPU: Central Processing Unit

HMD: Head-Mounted Display

GPU: Graphics Processing Unit

NPC: Non-Playable Character

PPE: Personal Protection Equipment

VR: Virtual Reality

VE: Virtual Environment

VRT: Virtual Reality Training

PROJECT PARTNERS

CIRCE: Fundación CIRCE Centro de Investigación de Recursos y Consumos Energéticos

FRAUNHOFER: Fraunhofer Gesellschaft zur Förderung der Angewandten Forschung e.V.

POLITO: Politecnico di Torino

EPROPLAN: EPROPLAN GmbH Beratende Ingenieure

SINERGIE: Sinergie Società Consortile a Responsabilità Limitata

ENGIE: ENGIE Lab CRIGEN

SERNAUTO: Asociación Española de Proveedores de Automoción

AEN: Automotive.Engineering.Network – Das Mobilitätscluster e.V.

MESAP: Centro Servizi Industrie SRL

MOV'EO: Pole Mov'eo – Mobility Competitiveness Cluster

EPC: EPC Project Corporation Climate. Sustainability. Communications. mbH

MERIT GR: MERIT Consulting House – Olokríromenes Symvouleftikes Ipiresies Epixeiriseon Idiotiki

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PUBLISHABLE SUMMARY

Within WP3 “*Development of the training methodology and E2DRIVER platform*”, this deliverable D3.4 “*Virtual Reality training material*” contains all the information required to deliver, through the project platform, the virtual reality (VR)-based training planned in E2DRIVER.

Based on the analysis of needs in WP2 “*Benchmarking and analysis of training programmes at the automotive sector*”, in Task 3.4 “*Development of virtual/augmented reality training material*” activities have been devoted to define a VR training that could address the above needs while contributing at providing content identified in Task 3.1 “*Information gathering and repository development*” that could fit the holistic training plan designed in Task 3.2 “*Development of the overall training methodology*”. The VR training has also been conceived as a module that can be activated as needed according to the adaptive strategy devised in Task 3.3 “*Customized training plan module development*”.

In particular, by considering that the well-known potential of VR when applied to learning pertains the possibility to recreate scenarios that may be critical to manage for real (e.g., because too dangerous, costly, etc.) together with the opportunity for trainees to engage into realistic, physical *hands-on* experiences, the topic selected for the VR training is that of measurements on electric cabinets, a step which is fundamental for gaining a proper understanding of a company’s performance in the context of energy audits.

Within this task, a VR training platform has been developed targeted to expected users. The training experience has been shaped as a *serious game* (or, a “game with a purpose”), in which trainees immerse themselves into a three-dimensional world, are instructed on how to perform a certain set of measurement operations by interacting with it, and their performance is evaluated. A generic virtual environment has been created, with common elements that could be found in various settings, thus supporting both the replicability into multiple companies and factories as well as the sustainability of the initiative. In the future, assets created for the VR platform could be reused, e.g., to make the platform evolve in the augmented reality (AR) perspective, by letting trainees live not just a totally virtual experience, but a mixed one, in which virtual elements are overlapped to the real world.

The platform includes two major *interactive scenarios*. The scenarios focus on two different measurement operations, implying diverse safety requirements. The platform supports, for both the scenarios, two *training modes*, named “guided”, and “evaluated”. In guided mode, a *voice-over* (e.g., from a virtual trainer) explains step-by-step the operations to perform. Explanations are accompanied by visual cues (like blinks, highlights, etc.), helping the trainee to understand relevant concepts. Errors are corrected, so that the trainee experiments all the correct operations. In the evaluated mode, there is no audio or visual cues; the trainee needs to complete the operations autonomously (under conditions that could also vary) and, at the end, he or she receives a report with the outcomes of performed actions.

This report illustrates the process followed in designing the VR platform. It includes a description of the operations to perform in two scenarios, the text of the voice-over and the list of errors the trainees could make in their experience (which are checked by an evaluation logic). A mechanism for making evaluation data collected in the VR experience accessible in the project platform through activities performed Task 3.5 “*Platform development and modules integration*” is also presented. Finally, a user guide for the platform is also provided, reporting minimum requirements, installation instructions and information on how to interact in the virtual environment (move, grab objects, etc.).

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1 INTRODUCTION

Immersive virtual reality (VR) is widely used as a training instrument in non-formal learning contexts. This technology is particularly useful to train operators whose work takes place under dangerous conditions (in case of natural disasters, or in presence of hazardous equipment/operations). Moreover, with a VR-based training system it is possible to cut the costs of training and flexibly organize the activities.

Since measurement procedures on electric cabinets put the operators and the environment at risks (electric shocks, electric arcs, possible damages to expensive instruments, possible black-outs, potential causes of fire), the operators must be well-trained: the procedure must be known, the potential risks must be recognized and avoided, and safety precautions in place must be followed. Due to these safety issues, ordinarily this process is supported by a specific training process that gives access to a professional certification. However, theory may be not enough, whereas practice may expose them to the same risks they must avoid. The use of VR technology can represent a powerful solution to overcome these difficulties.

This document presents a VR application developed by the hub of the VR@POLITO at the Department of Control and Computer Engineering of Politecnico di Torino in the context of the E2DRIVER project Task 3.4 “*Development of virtual/augmented reality training material*”. The steps for the development of the application are entirely described, from the conceptualization to the actual implementation. The material used and produced in the above steps can be found in this document (3D models, manuals, etc.), along with the storyboard of the application and the text of the voice-over used in the simulated virtual environment.

The application is a training instrument that allows users to learn a procedure for performing measurements on electrical cabinets in two scenarios, practice all the required operations and interactions and receive an evaluation based on demonstrated knowledge and skills. Four videos of these scenarios are available at this [link](#). A possible method to use this training instrument is described, along with instructions and guidelines to follow during the first use of the application.

It is worth remarking that the application was developed following the guidelines in European Standard EN 50110-1 “*Operation of electrical installations – Part 1: General requirement*” and in IEC 61243-3:2014. Measurement operations that are considered imply diverse safety requirements. Before performing these operations on real equipment, it is strictly required to complete a training about occupational risk prevention to become a person adequately advised or supervised by electrically skilled persons or with relevant education and experience to perceive risks and to avoid hazards which electricity can create, as well as to fulfill the proper EU or national requirements. These instructions are not included in the E2DRIVER training application, which has the aim of showing the process in a virtual way that is intrinsically ‘safe’. A warning on these aspects is included also in the application.

The rest of the document is organized as follows. Chapter 2 presents an overview on VR and VR training, focusing on the pros and cons and the possible application fields. Chapter 3 describes the design and the overall structure of the VR application. Chapter 4 is the transcription of the storyboard used in the development steps. Chapter 5 describes a procedure to use the application as a training instrument and proposes a method to validate it. Chapter 6 offers a guide to set up and run the application.

2 VIRTUAL REALITY TRAINING

This chapter presents an overview on VR, its use in training contexts, its aim (along with its pros and cons), and its target.

2.1 Virtual Reality (VR)

The term VR identifies experiences where a user interacts with a Virtual Environment (VE). This virtual environment can be the product of imagination or a reproduction of a real one; in both cases, the important point is that the environment must be interactive and credible. Based on this definition, VR comprehends desktop, low-immersion, applications, along with applications characterized by a high level of immersion and developed for Head-Mounted Displays (HMDs).

For VR applications, and particularly in the case of highly-immersive ones, it is imperative that the user feels that he or she belongs to the VE. If that is not the case, the virtualization becomes an obstacle for the user, therefore ruining the experience and missing the goal for which the application was developed.

There are two key concepts that characterize a VR application, namely *immersion* and *presence*.

- Immersion is the feeling of being physically present in a VE, and it depends on the sensorial fidelity of the simulation. To achieve a high level of immersion, it is necessary to stimulate several user's senses in different ways: 3D objects must behave like the user expects, actions must be followed by reasonable reactions (if the user grabs an object, the object must follow the hand, and if the user drops the object, the object must fall), etc. In summary, the VE must behave in a plausible way. As said, it is important to stimulate several senses, but it must be noticed that it is not necessary to stimulate them all: depending on the purpose of a VR application, it may be sufficient to focus on a subset of senses in order to achieve a sufficient level of immersion.
- Presence is the subjective feeling of being part of the simulation. It can be enhanced by a high level of immersion, but high levels of immersion do not imply high levels of presence. It depends on many factors, and it is linked to the concept of "suspension of disbelief" [1].

A VR application, to be successful, must be characterized by high immersion and high presence.

2.2 Aim and Intent

VR is strongly linked to the field of entertainment and videogames. The first immersive VR applications were developed at the beginning of the second half of 1900 and they were limited and expensive, but it is thanks to the videogame industry that VR technologies started to develop again in recent years.

The recent boom in the field of VR was successful from a technological point of view, but unsuccessful from a commercial perspective: new powerful HMDs came to the market, but they were still expensive and, therefore, unaffordable for the average user. In addition, the few gaming applications developed for HMDs were simple, often alternative versions of pre-existing games (therefore not optimized for immersive VR). Only in the last few years, HMDs started to be more common, and more serious gaming applications started to be developed.

All these factors led to a situation in which powerful and expensive HMDs could not be used for the purpose they were intended for. It is in this context that immersive VR *serious games* started to be developed.

A serious game is an application (a game) developed with a purpose different than pure entertainment. Many examples of serious games, with different grades of immersion, are available nowadays: flight simulators, driving simulators, training applications, etc. Since HMDs were too expensive for the average user, but affordable for industries or associations, the use of immersive technologies shifted from the creation of applications for mass entertainment to the development of specific simulations, often used for research or training.

2.3 Training in VR

VR training (VRT) is suitable to be used as a complement to or as a substitute for classic exercises. In particular, immersive VR applications can be successfully used to simulate procedures where the user must interact directly with multiple objects, whereas they are not recommended when the user is passive or must interact with screens, keyboards, etc. (it is possible to create such applications, but the immersive technology would fail to enhance the experience).

VRT applications bring a series of advantages with respect to the real exercise, especially if the context of these exercises involves dangerous conditions and expensive equipment, or if the exercises are expensive, time consuming or difficult to organize. In particular, a VRT session is:

- less expensive, since it is only necessary to pay once for the development of the application, and then it can be (re-)used freely;
- easier to organize, since it is only necessary to distribute the software and the required equipment, and it is not necessary to organize travels to gather all the involved stakeholders (this point is particularly important nowadays, due to COVID-19 pandemic situation);
- more complete than a real exercise, since in a VE it is possible to simulate situations that are difficult to recreate in the real world (for example, it is possible to simulate severe accidents or large-scale disasters);
- easily repeatable, since it is possible to launch the application multiple times;
- safer, since it is possible to simulate dangerous situations, with a decent level of realism, without really exposing the users to the corresponding risks.

3 VR SIMULATION

The application developed in the E2DRIVER project is an immersive VR simulation, and it is deeply described in the following sections. The creation of a desktop version of the same application was considered, but not implemented, though certainly feasible in the future based on developed assets.

Measurement operations on a low-voltage three-phase electrical switchboard are considered as they are important in the process of assessing energy performance of industrial premises. To this aim, one of the most common instruments for measuring and data logging of electrical power flows, the Dranetz PowerGuide® 4400 (a portable, hand-held, eight-channel power quality meter/monitor), has been taken as an example for the development of the application [2], but the document will refer to a generic “measuring instrument” in order to provide a more abstract description, showing the replicability potential of the implemented methodology.

The measurement operations generally encompass two parts:

- An assembly and measuring part, in which the user makes the electrical connections between the measuring instrument and the switchboard panel in order to perform energy and power measurements.
- A disassembly part, in which the user removes the connections made in the previous part and downloads collected data from the measuring instrument.

Only the first part is considered for the simulation, since it is more significant from the educational viewpoint that is relevant for the E2DRIVER project.

3.1 Technology

To develop an immersive VR application, high-end hardware is required: powerful Graphics Processing Units (GPUs) and fast Central Processing Units (CPUs) are necessary to obtain a smooth simulation (without lags or other problems). The constraints on the GPU type are dictated by the use of an HMD, whereas the constraints on the CPU type are determined both by the use of an HMD and the use of particular assets and libraries to manage the physics of the simulation.

To develop the application, three workstations have been used, with various CPU/GPU configurations (Intel i5 with NVIDIA GTX 970, Intel i7 with NVIDIA RTX 1060, and Intel i9 with NVIDIA RTX 2080 Ti), in combination with three different HMDs:

- HTC Vive;
- HTC Vive Pro;
- Oculus Quest.

The first of the three workstations respected the minimum requirements for the use of an HMD, but it was discarded during the development because it was not powerful enough to run the final simulation. The second of the three workstations could run the final simulation, but it showed different stability problems during the development phase (when the requirements are heavier). The third workstation was equipped with GPU and CPU that were significantly more powerful than those required to run the final application; thus, it could run the simulation smoothly, even in the development phase.

As for the software, the application was developed using Blender to create the 3D models, Microsoft Visual Studio to write the code and create the core logic of the VR simulation, Gimp to create 2D textures and images, and Unity as game engine (to put together models, code and images and create the simulation).

3.2 Development

The development of the E2DRIVER application started with a study of the domain and of the procedures followed during operations on electrical cabinets. With the help of the experts from the Department of Energy of Politecnico di Torino, several procedures (on different cabinets) were filmed and documented in order to collect information and references for a future use.

These references were then used to develop a *design document*, a text file describing a first version of the application, with a rough outline of: all the procedure steps (this text file later became the first scenario of the final application), the possible choices offered to the user, and the possible errors to consider during the simulation. With the help of the experts, this document was then refined and extended: the presented scenario was enriched and translated in a storyboard, the evaluation was added, a second scenario was then conceptualized and formalized, etc. In the end, the design document became the first draft of this deliverable.

In parallel to the work on the design document, the development of the application began. When the scenarios were still to be defined, the development focused on the creation of the basic interaction logic (grabbing an object, opening a door, turning on the measuring instrument, etc.). These interactions were scenario-agnostic, since they could be used at a later time and they did not depend on the final procedure. At this stage, all the interactions were performed on primitive geometric 3D objects.

When the interactive scenarios started to take shape, the actual 3D models were added to the application, and more specific interaction logics were created (for instance, the various features of the measuring instrument). Finally, a guiding system was added to the simulation, along with an evaluation logic: an initial version of the first scenario was then completed, and it had only to be tested and refined.

With the completion of the first scenario, the efforts moved on debugging, testing, and to the creation of the second scenario. Some interaction logics and some models were reused, whereas others needed to be created (Personal Protective Equipment, or PPE, the new guiding system, the new evaluation logic, etc.)

3.3 Scenarios

The measurement process on the low-voltage switchboard can take different options depending on the operative conditions of the electrical equipment. The guidelines in the European Standard EN 50110-1 “*Operation of electrical installations – Part 1: General requirement*”, have been implemented. According to the guidelines, in some cases, a backup line can be available and some operations can be performed after disconnecting the conductors from the main electrical line, removing the danger of electrical shock from contact voltage. Moreover, inside the switchboard, some further protections can be installed like, for instance, plexiglass separators that prevent access to live conductors.

The modelling of these alternatives gives rise mainly to two different scenarios that are described in the following.

- **First scenario:** in the switchboard there are plexiglass separators and a backup power line; therefore, according to the above guidelines, the user can operate without the need of a specific PPE (Figure 1).

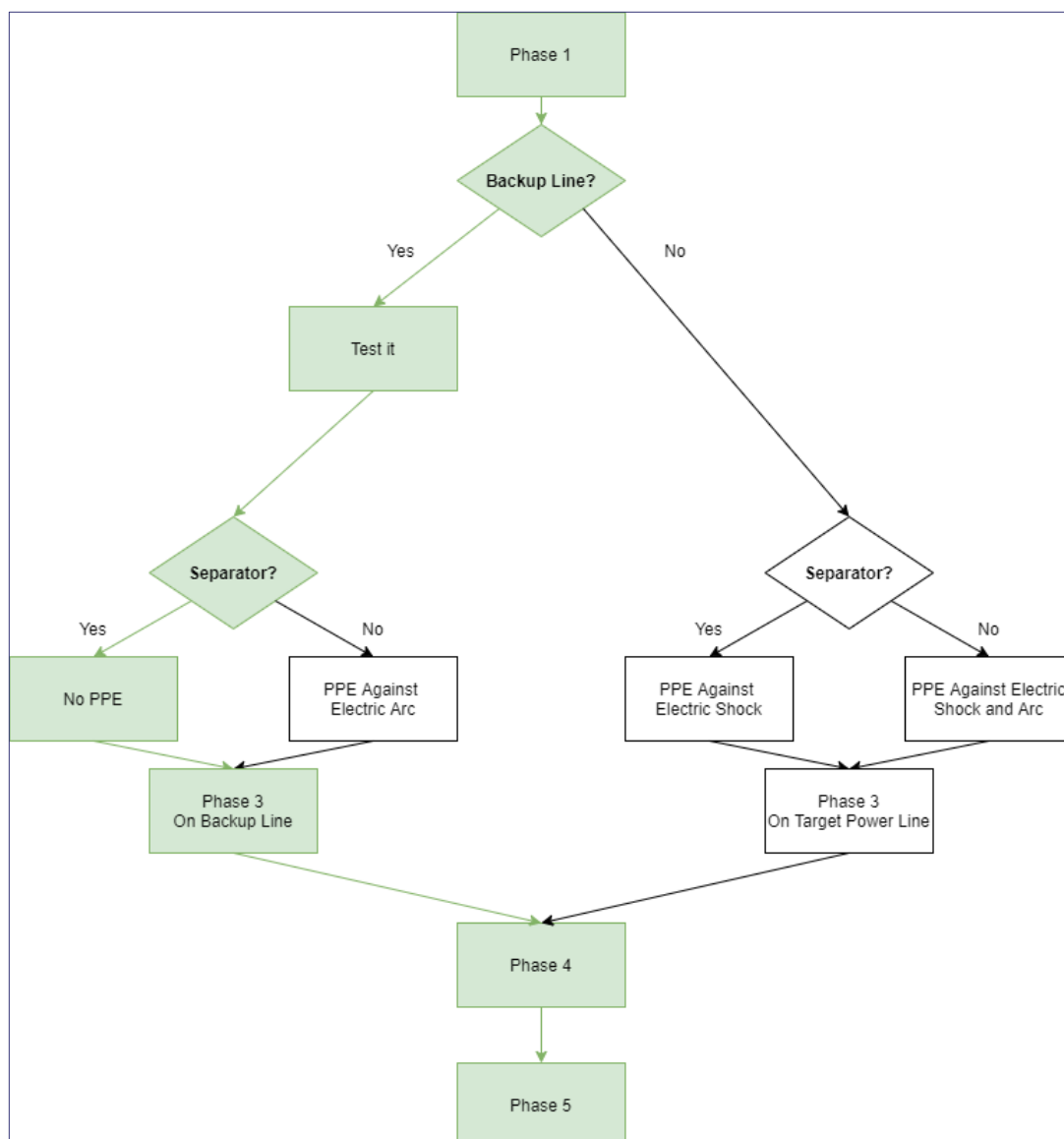


Figure 1: First scenario – Flowchart (left branch)

- **Second scenario:** the switchboard has no backup power line and no plexiglass separator; therefore, the user needs to wear the proper PPE in order to avoid electric shocks and electric arcs (Figure 2).

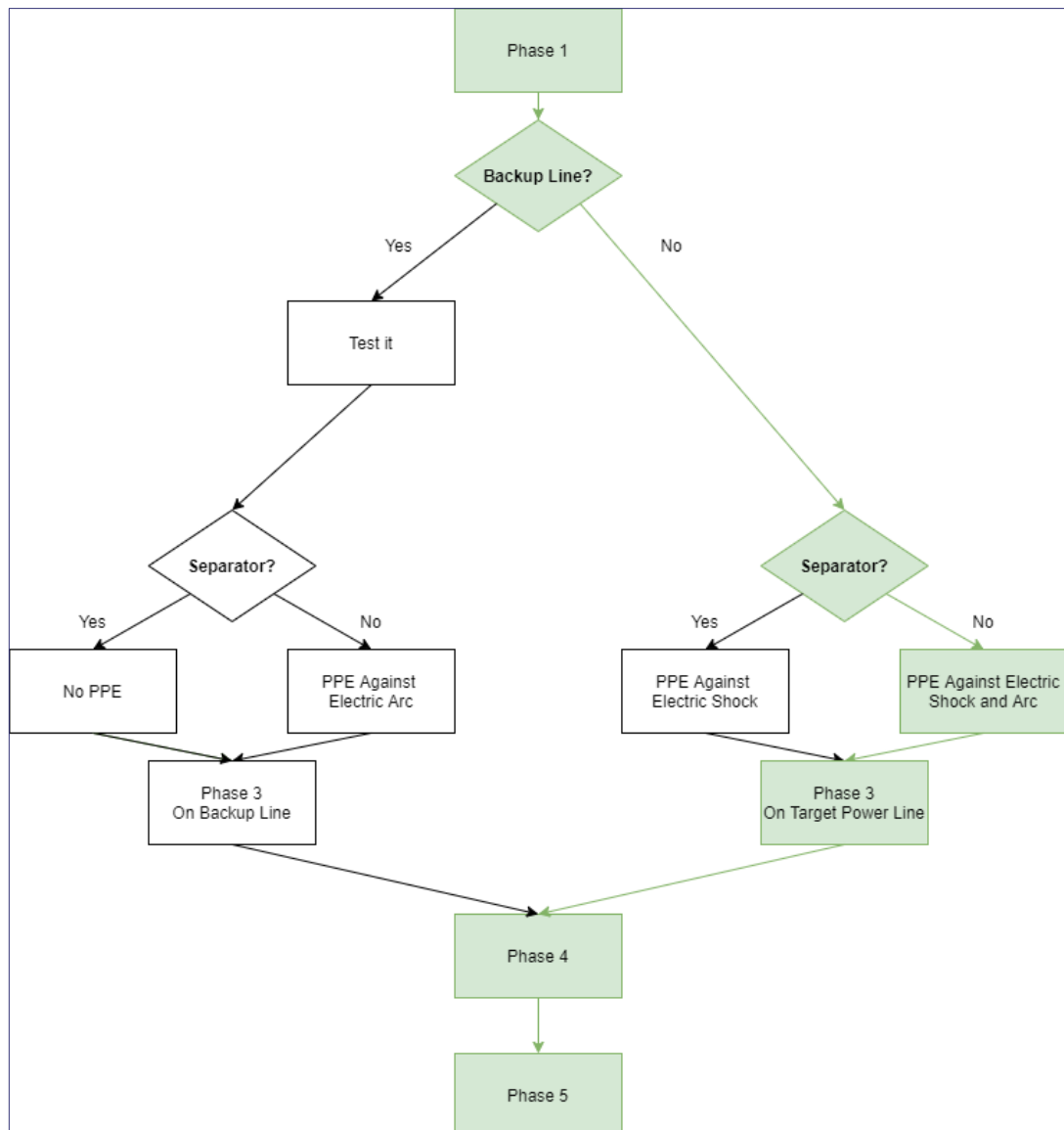


Figure 2: Second scenario – Flowchart (right branch)

Each scenario can be subdivided in the following phases.

- **Phase 1.** The user enters the simulation room and takes the first steps in the virtual world in order to familiarize with it and with technology. He or she tries the locomotion and the interaction systems.
- **Phase 2.** The user opens the switchboard and chooses the proper PPE. If there is a plexiglass separator between the power lines, there is no need for the PPE against electric arcs. If there is a backup power line, there is no need for the PPE against electric shocks (but the safety of the backup power line must be tested according to *IEC 61243-3:2014 Live working - Voltage detectors - Part 3: Two-pole low-voltage type*).

- **Phase 3.** The user makes the voltage connections on the backup power line (if present) or the power line labeled 'Lab'.
- **Phase 4.** The user chooses the correct electrical clamps and makes the current connections on the 'Lab' power line.
- **Phase 5.** The user configures the measuring instrument to make long-term measurements, place a warning signal in front of the exposed conductors, then leaves the room.

The choices made in Phase 2 bring to a total of four possible configurations, each one differing because of the required PPE and the optimal approach to the measurement procedure; for example, if there are plexiglass separators and backup power lines, no PPE is needed and the best strategy is to make voltage connections on the backup and current connections on the target power line.

3.4 3D Models

In the following, the main 3D models created for the simulation are illustrated. For each model, a photo of the reference is provided.

- **Dranetz 4400AA**

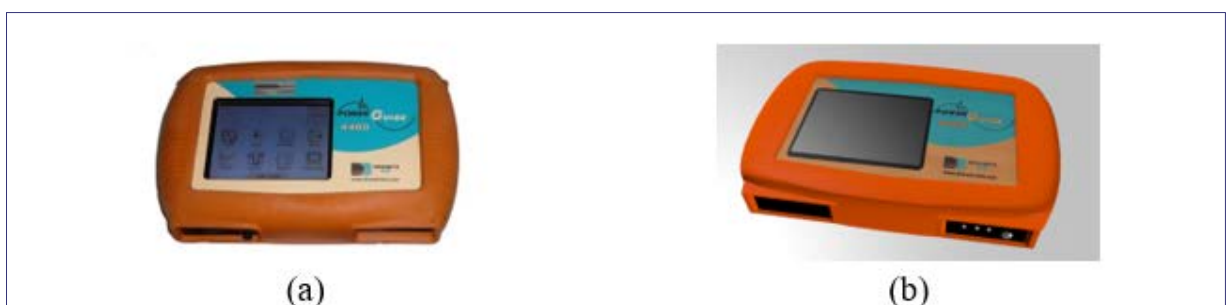


Figure 3: Dranetz 4400, (a) photo and (b) 3D model

- **Probes**



Figure 4: Current clamp, (a) photo and (b) 3D model

- **Room**

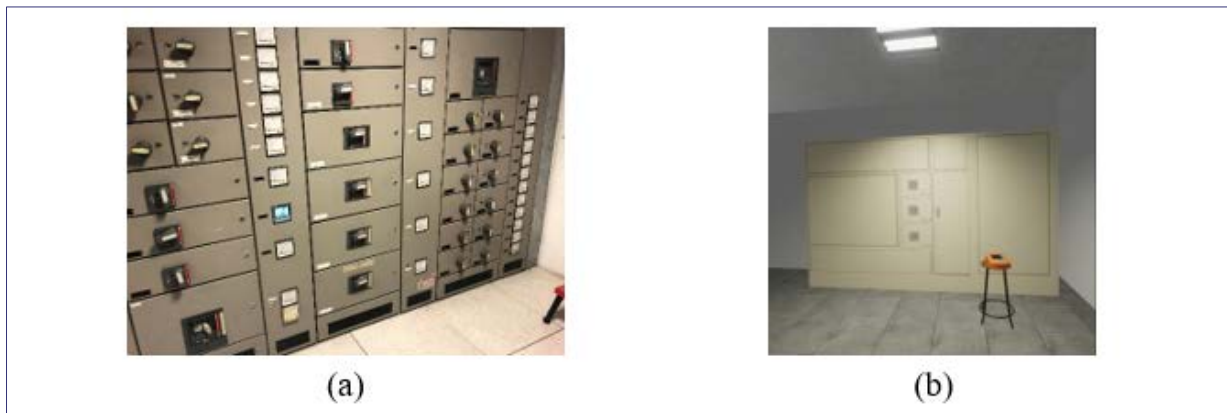


Figure 5: Room, (a) photo and (b) 3D model

- **Transformer enclosure**



Figure 6: Transformer, (a) photo and (b) 3D model

- **PPE**



Figure 7: Helmet, (a) photo and (b) 3D model

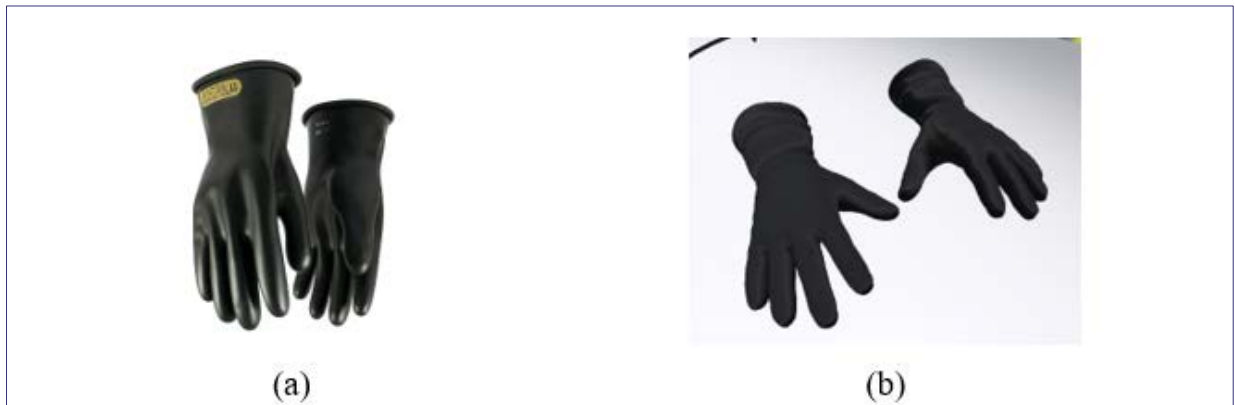


Figure 8: Gloves, (a) photo and (b) 3D model

- **Tester**



Figure 9: Tester, (a) photo and (b) 3D model

3.5 Modes

Each scenario includes two *training modes*, Guided mode and Evaluated mode. The Guided mode describes the measuring procedure step-by-step, whereas the Evaluated mode can be used as a testing experience to verify the user's knowledge of the procedure and required operations. Both modes are based on the instrument's guide (the Dranetz 4400 in this case, Figure 10) and from consultation with experts.

Safety precautions

The following safety precautions must be followed whenever any type of voltage or current connection is being made to the 4400.

- Wear proper Personal Protective Equipment, including safety glasses and insulated gloves when making connections to power circuits.
- Hands, shoes and floor must be dry when making any connection to a power line.
- Before each use, inspect all cables for breaks or cracks in the insulation. Replace immediately if defective.
- Press the 4400 On/Off power button to Off.
- Before connecting to electric circuits to be monitored, open their related circuit breakers or disconnects. DO NOT install any connection of the 4400 to live power lines.
- Connections must be made to the 4400 first, then connect to the circuit to be monitored.

Figure 10: Safety precautions for the Dranetz 4400

3.5.1 Guided Mode

In the Guided mode, a voice-over coming from a guide (not shown, though in the future the guide may be represented by a Non-Playable Character, NPC) explains each step of the simulation. A single instruction pronounced by the voice-over describes a concept or action to be performed, and the user must wait for the end of an instruction in order to proceed with the operations.

In this mode, the user is supposed to follow the voice-over. To enforce this concept, three solutions are implemented:

- the 3D objects mentioned by the voice-over blink (Figure 11);
- the last messages given by the voice-over is repeated, if needed;
- the available interactions are limited (in the Guided mode, the user will be allowed to interact only with the correct virtual objects).

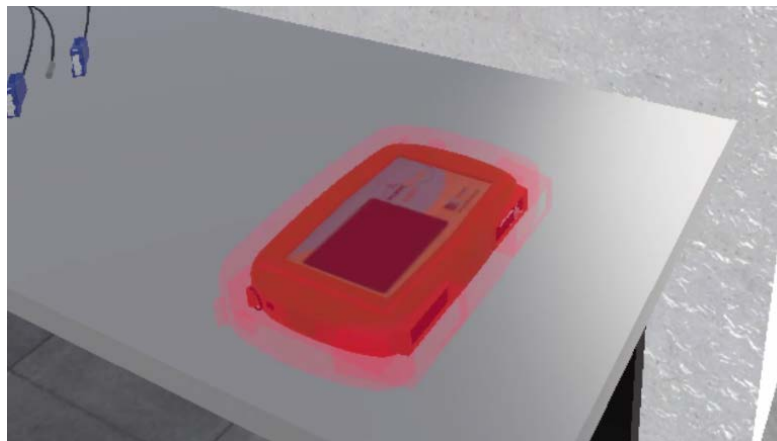


Figure 11: Guided mode – Object blinks

3.5.2 Evaluated Mode

In the Evaluated mode, the user can move freely inside the virtual environment and interact with the objects in the scene. It is possible for him or her to be evaluated on the chosen scenario. The user's actions are tracked and evaluated, and a report is produced at the end of the simulation. There is no voice-over apart from a brief introduction that describes the simulation.

4 STORYBOARD

The storyboard of the simulation is described in this chapter. The term “Voice” coloured blue is used to identify the voice-over coming from outside the virtual room, both for the first and second scenario. The term “Voice” coloured yellow highlights the instructions exclusive for the second scenario. The scenarios are divided in phases; for each phase, a series “Avoided errors” (possible mistakes that are avoided thanks to the voice-over), marked in red, are described.

4.1 Disclaimer on Safety Aspects

At the beginning of the simulation, a warning illustrates the scope of the developed VR application.

Warning: This application was developed following the guidelines in European Standard EN 50110-1 “Operation of electrical installations - Part 1: General requirement” and in IEC 61243-3:2014. The intent of the application is to present measurement operations implying diverse safety requirements. Before performing these operations on real equipment, it is strictly required to complete a training about occupational risk prevention to become a person adequately advised or supervised by electrically skilled persons or with relevant education and experience to perceive risks and to avoid hazards which electricity can create, as well as to fulfill the proper EU or national requirements. These instructions are not included in this E2DRIVER training application, which has the aim of showing the process in a virtual way that is intrinsically “safe”.

4.2 First Scenario

In the switchboard there are plexiglass separators and a backup power line. The user can use the backup power line to safely make voltage connections; the plexiglass separators protect him or her from electric arcs. To use the backup power line without the PPE, it is necessary to test if the corresponding switch works properly using a tester or “hand-held two-pole voltage detector” according to IEC 61243-3:2014. To use the tester, it is first necessary to wear the protective gloves and the helmet. The gloves and the helmet can be removed after the tester confirms that the backup power line is safe to use.

- Phase 1.** The user begins the simulation inside the virtual room, far from the electrical switchboard. Various objects are in the room: the electrical switchboard itself, a table, some stools, a closet containing the PPEs, etc.
 A message from the voice-over explains the interface used for the application and the possible interactions with the virtual world. This phase is useful to separate the complexity of the VR interface from the complexity of the measurement procedure.

Voice 0: “Welcome to the First scenario of the Guided mode of the simulation for training to the use of measuring systems. If you want to move in the virtual world, you can walk physically within the virtual room boundaries. You can move also using the arm swing method: press the Grip buttons on the hand controllers and swing your arms back and forth towards the desired position.

A voice will guide you during the procedure with a series of instructions. Each instruction will describe the task that you have to perform to proceed in the simulation. If you are stuck and

no instruction is playing, you can replay the last message by using the Touchpad on one of the controllers”.

Voice 1: “If you want to interact with a virtual object, touch it with one of the virtual controllers. If an interaction is possible, the object will be highlighted. Interact with the object by pressing the Trigger button on the controller. Now, grab the measuring instrument placed on the table. Once an object is grabbed, you can pass it from one hand to the other or place it into the scene. To proceed, place the instrument on the stool near the electrical switchboard”.

The user moves towards the measuring instrument and interacts with it (he or she can grab it, turn it on, etc.) or with the various electrical probes in the scene (the probes are placed on a table). When confident enough, he or she shall connect the measuring instrument to the power supply and place it near the switchboard.

Voice 2: “Remember to connect it to the power supply using the charger. Plug one end of the charger in the socket on the right side of the measuring instrument and the other end in the electrical socket on the wall”.

The user connects the instrument to the power supply.

Avoided errors:

- The user does not connect the measuring instrument to the power supply, thus invalidating the whole procedure (if the instrument is not on charge, it will turn off during the measuring period and the output will be void or only partial).
- **Phase 2.** The user opens the electrical switchboard and looks at the power lines. The voice-over tells that the user’s task is to make measurements on a certain power line (at present named ‘Lab’, but the name can be changed). In this scenario, the enclosure has a backup line and the power lines are divided by plexiglass separators.

Voice 3: “Your task in this simulation is to make power measurements on the line named “Lab”. To identify the line, look at the labels placed near the electrical switches. Notice also the backup power line placed above. To proceed, open the electrical switchboard door”

Voice 4: “You can use the backup power line to safely make voltage measurements without the need for a Personal Protective Equipment, or PPE, to protect yourself against electric shocks. First, move the backup power line switch to ‘Open’”.

Voice 5: “If the backup power line switch works properly, you can use the backup power line to safely make voltage measurements without the need for a Personal Protective Equipment, or PPE. Before making this assumption, it is necessary to test the switch. To use a tester, the PPE is necessary. You can find the PPE in the closet near the blue door. Locate it to proceed”.

Voice 6: “Take the protective gloves and the helmet with the protective screen from the closet, in order to guard yourself from electric shocks and electric arcs. Once you finished, go near the switchboard.”.

Voice 7: “It is now time to test the backup power line switch. The switchboard has plexiglass separators that protect you from potential electric arcs between the different power lines. Remove the plexiglass separators from the backup power line” (Figure 12).

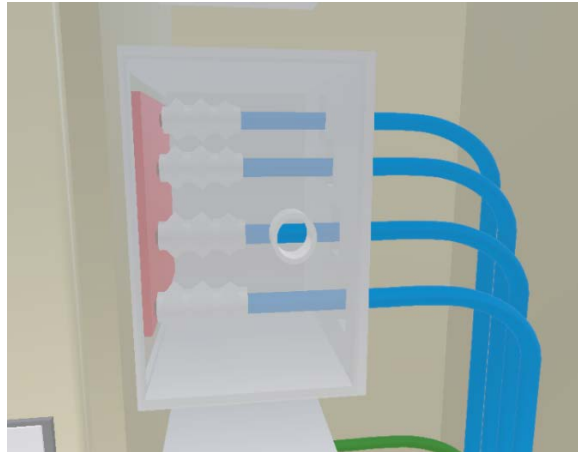


Figure 12: Plexiglass separator

Voice 8: “The backup power line has four protective covers. Remove them to expose the conductors”.

Voice 9: “You can now test the power line. The tester is located in a case near the switchboard. Notice that one of the two ends of the tester has a screen.”.

Voice 10: “Take both ends of the tester from the case. Without dropping the instrument, place the end with the screen near the first conductor of the backup power line, and the end without the screen near the fourth conductor. If you see a warning sign on the screen and you hear an alarm, it means that the power line is not safe to use without PPE”.

Voice 11: “The backup power line is safe to use. You should check all the conductors of the line, but for now let’s continue with the procedure. Since the backup power line is safe, you can remove the PPE. Interact with the box in the closet where you found the PPE to remove the gloves and the helmet”.

Avoided errors:

- The user “trusts” the switch and does not check if it is safe to operate without PPE.
 - The user tests the switch without PPE, exposing himself/herself to potential risks.
- **Phase 3.** The user makes voltage connections on the instrument and the enclosure. When the backup power line is present, the user can make voltage connections directly on it; in fact, the backup power line is unused, and can be turned on and off. If the user makes connections on the turned-off backup power line, he or she does not need the PPE against electric shocks.

Voice 12: “Now it is time to make the necessary connections on the measuring instrument, so find it in the scene. Remind that the electrical probes must be plugged into the measuring instrument before connecting them to the conductors. To facilitate the next steps of the procedure, it may be useful to grab the measuring instrument or place it vertically on the stool with the upper part facing up”.

Voice 13: “In the upper part of the measuring instrument you can find a total of twelve sockets” (Figure 13).

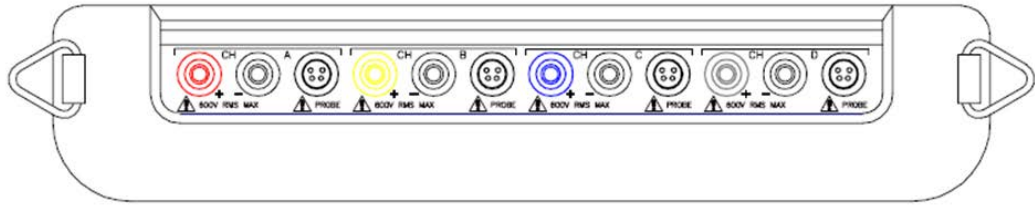


Figure 13: Dranetz 4400 – Top view

Voice 14: “The sockets are organized in groups of three; each group can be used to make a measurement on a different phase”.

Voice 15: “Each group consists of two sockets for the voltage connections (a colored one for the high value and a black one for the reference value) and a third socket for the current connection”.

Voice 16: “Start with the voltage measurements. The crocodile clips have different colors to facilitate this operation: you should plug each crocodile clip into the socket of the same color. If you have problems during the following operations, put the measuring instrument vertically, with the sockets facing up”.

Voice 17: “Take both ends of the red crocodile from the table and plug the jack into the red socket in the first group. Leave the crocodile near the instrument”.

Voice 18: “Take both ends of a black crocodile from the table and plug the jack into the black socket, in the same group as before. Leave the crocodile near the instrument”.

Voice 19: “You should proceed in the same way for the other clips, plugging each crocodile into the socket of the same color. For now, let’s jump ahead to the next phase”.

The screen fades to black and, after a brief pause, the other crocodile clips are automatically connected to the sockets; although the software internally manages the connection of all the clips, for the sake of shortening the simulation duration the repeated operations have been removed as they would not add too much to the training experience.

Voice 20: “Now that all the crocodile clips are connected to the measuring instrument, you have to make the connections in the electrical switchboard. In this simulation, you will measure the value of the first three voltages”.

Voice 21: “with respect to the fourth one (also called neutral),”.

Voice 22: “and the value of the neutral with respect to ground. You can find the ground in the lower part of the switchboard” (Figure 14).

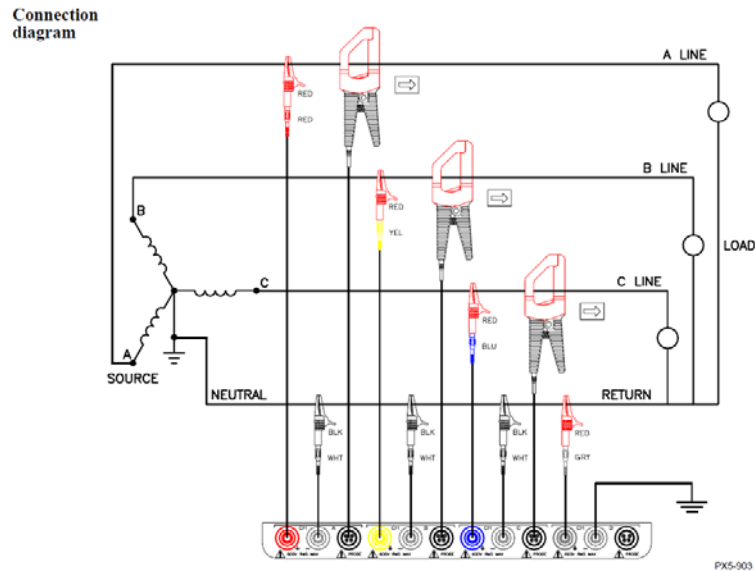


Figure 14: Three-phase circuit measure

Voice 23: “For each of the first three groups of sockets of the measuring instrument, connect the colored crocodile clips to one of the first three exposed conductors. Connect the red crocodile to the first conductor to measure the first voltage”.

Voice 24: “Connect the corresponding black crocodile to the fourth conductor”.

Voice 25: “Connect the yellow crocodile to the second conductor”.

Voice 26: “Connect the corresponding black crocodile to the fourth conductor”.

Voice 27: “Connect the blue crocodile to the third conductor”.

Voice 28: “Connect the corresponding black crocodile to the fourth conductor”.

Voice 29: “The fourth group of sockets must be used to measure the neutral with respect to ground. Connect the white crocodile to the fourth conductor”.

Voice 30: “Connect the corresponding black crocodile to the Ground conductor”.

The user makes the connections and can move to the next phase.

Avoided errors:

- The user makes the connections on the wrong power line.
 - The user makes voltage connections directly on the ‘Lab’ power line without the correct PPE.
 - The user makes the connections on the power line before making the connections on the instrument.
 - The user makes connections on the instrument while it is turned on.
 - The user gets too close (30 cm) or touches the power line while the corresponding switch is on ‘Closed’; touching the power line will lead to a fatal error.
 - The user makes the wrong connections (not using all the clips, using the sockets in a wrong way, etc.)
- **Phase 4.** The user makes current connections using the current clamps. There are multiple types of clamps, which differ in size and current range. Clamps with a larger size can fit also smaller cables, but smaller clamps cannot be used on larger cables. Clamps with a certain range

can be used on cables with a different range, but the measures will be less precise or even wrong. The connections must be made directly on the 'Lab' power line. At the beginning of this phase, the measuring instrument is close to the switchboard and connected to the backup power line. The current clamps are on the table, near a sign that reports corresponding information in terms of size and range. The characteristics of the power lines are written near the switches.

Voice 31: "Now it is time for making the current connections. You can use different types of clamps: each type is optimal for a certain cable dimension and for specific current range. The information about the cable size and the current range can be found near the power line switch".

Voice 32: "In this case, you must make connections on cable of diameter of 3 cm and current above 30 Ampere, so you should use the clamps of type TR 2500 A. Take three clamps of type TR 2500 A from the table and connect the jacks to the first three groups of sockets on the measuring instrument" (Figure 15).



Figure 15: Two different current clamps

The user makes the connections on the instrument.

Voice 33: "Now it is time to make the connections on the cables of the 'Lab' power line. Remind that the same order used for the voltage connections shall be followed. Each clamp can be oriented in two different ways; the orientation will change the value of the final output. All the clamps must have the same orientation. The 'Arrow' mark must point to the right and be consistent with the direction of the current flowing from the switch to the electrical user".

Voice 34: "Connect the clamp of the first group to the first cable of the 'Lab' power line. The "Arrow" mark must point to the right".

Voice 35: "Connect the clamp of the second group to the second cable of the 'Lab' power line. The "Arrow" mark must point to the right".

Voice 36: "Connect the clamp of the third group to the third cable of the 'Lab' power line. The "Arrow" mark must point to the right".

The user makes the connections on the enclosure and he or she is ready to move to the next phase (Figure 16).

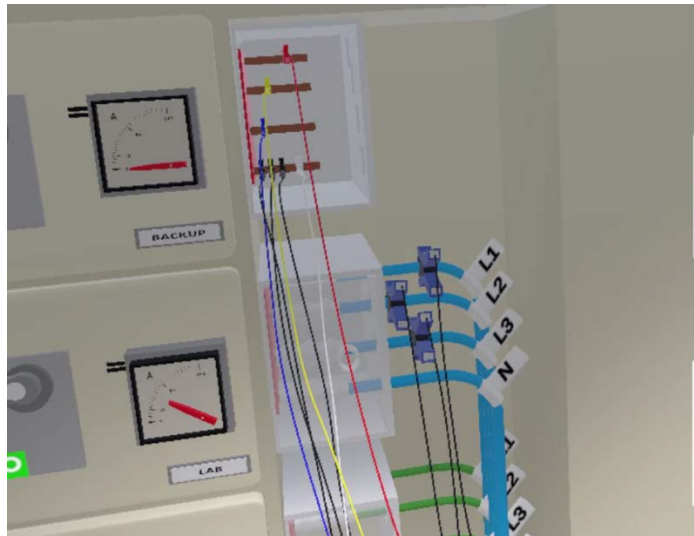


Figure 16: First scenario - Connections made on the switchboard

Avoided errors:

- The user makes connections on the wrong power line.
 - The user connects the clamps in a wrong way (for example, with a wrong orientation).
 - The user makes the connections on the power line before making them on the instrument.
 - The user makes connections on the instrument while it is turned on.
- **Phase 5.** All the connections are completed. The user turns the measurement instrument on, selects the correct type of clamps from the corresponding menu on the instrument itself, checks all the connections and set the instrument up.

Voice 37: “Now that all the connections are completed, you can close the backup powerline switch”.

Voice 38: “It’s now time to configure the instrument for the long-term measures. First, turn on the instrument using the power button”.

Voice 39: “Start by choosing the type of clamp used for the connections. The instrument is now in the Main menu. From here, click on the ‘Start/Setup’ button” (Figure 17).

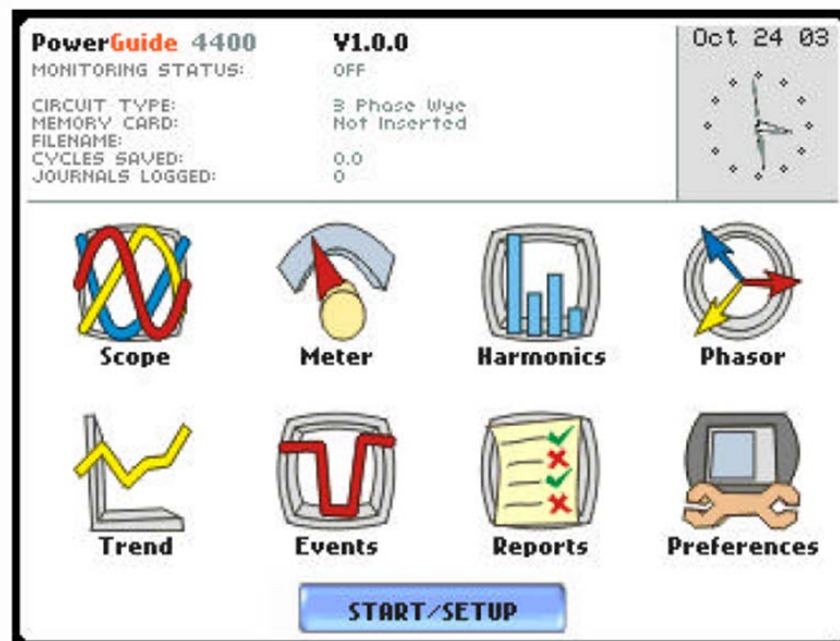


Figure 17: Measuring instrument – Main menu

Voice 40: “The instrument is now in the Setup Menu. Choose ‘Automatic Setup’ to use the default configuration” (Figure 18).

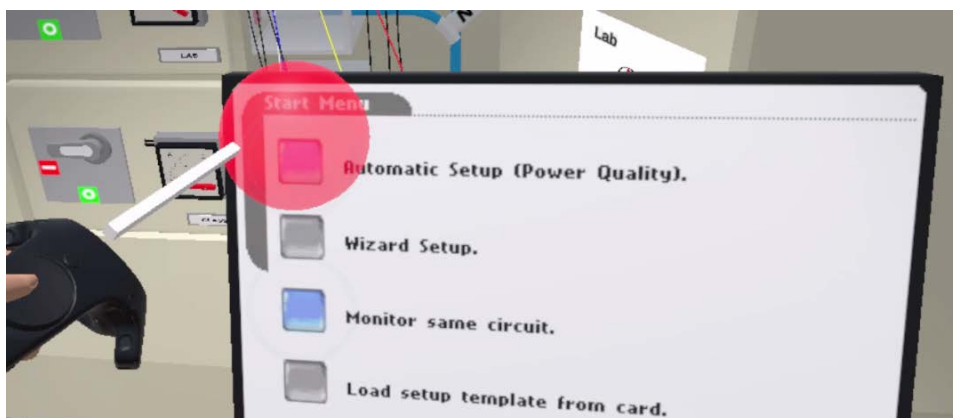


Figure 18: The user interacts with the interface of the measuring instrument

Voice 41: “Now, click on the ‘Probe’ button to select the clamp type”.

Voice 42: “In this case you used the same type of clamp for all the connections, so check the ‘Set Identical’ Box’.

Voice 43: “Click on the “Change” button to choose the clamps”.

Voice 44: “In this case you used clamps of type TR 2500 A, select it from the list”.

Voice 45: “Click OK to go back to the previous screen”.

Voice 46: “Click OK to go back to the previous screen”.

Voice 47: “Click OK to go back to the previous screen”.

Voice 48: “Click the Exit button to go back to the Main menu”.

The user navigates the menu and select the clamps.

Voice 49: “Now you are in the Main menu. Click on the ‘Phasor’ button to check the consistency of the phasors. If there is any error, you must change the connections”.

The user moves to the Phasor menu (Figure 19) to check the phasors.

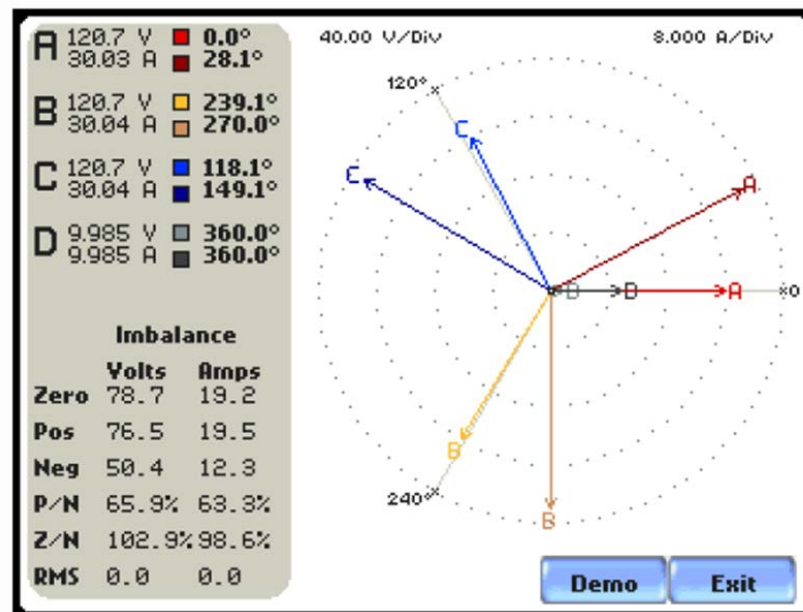


Figure 19: Measuring instrument – Phasor menu

Voice 50: “Everything is correct: the voltage values and the current values are positive; therefore, the corresponding phasors have the corrected orientation. Press the ‘Exit’ button to go back to the Main menu”.

Voice 51: “It is now time to set the last parameters for the long-term measures. Press the ‘Start/Setup’ button”.

Voice 52: “You are in the Setup menu. From here, press the ‘Monitor same circuit’ button”.

Voice 53: “You need to choose the monitoring period and the sampling interval. Start with the period. Press the ‘Monitor using Start and End times’ button”.

Voice 54: “Choose the final day of the monitoring period. Press the corresponding button”.

Voice 55: “Set a future date of your choice by using the Plus and Minus buttons. Once you finished, press the OK button to go back to the previous window”.

Voice 56: “Click OK to go back to the previous screen”.

Voice 57: “Now set the sampling interval. Press the “Modify Trigger Parameters and Intervals” button”.

Voice 58: “From here, press the ‘Journal Interval’ button”.

Voice 59: “Now press the ‘Power Values’ button to open the pop-up window”.

Voice 60: “Press the ‘Power Values Interval’ button to set the interval”.

Voice 61: “Use the Plus and Minus buttons to set a sampling interval of your choice. Press ‘Ok’ once you finished”.

Voice 62: “Click Ok to close the pop-up window”.

Voice 63: “Press the ‘Finish’ button to go back to the previous screen”.

Voice 64: “Press the ‘Exit’ button to go back to the Monitor menu”.

Voice 65: “From this menu, press the ‘Start Now’ button to arm the measuring instrument”.

The user sets the instrument up.

Voice 66: “Before leaving the room, it is necessary to signal the presence of exposed active conductors. Take the warning sign near the closet and place it near the measuring instrument”

The user places the sign.

Voice 67: “Now you can leave the room, go next to the blue door and interact with the handle to go back to the main menu of the application”.

The user moves towards the door and the simulation ends. The output of the measuring instrument is generated in the folder where the application executable is contained. The report containing the evaluation will be generated in the same folder only in the Evaluated mode.

Avoided errors:

- The user leaves the room without completing the setup or without connecting the instrument to the current source.
- The user selects the wrong clamps.
- The user does not set the measuring period or the sampling interval.
- The user does not place the warning sign.

4.3 Second Scenario

In this scenario, the switchboard has no backup power line and no plexiglass separator (Figure 20); hence, the user needs to wear the corresponding PPE to safely operate on the conductors.

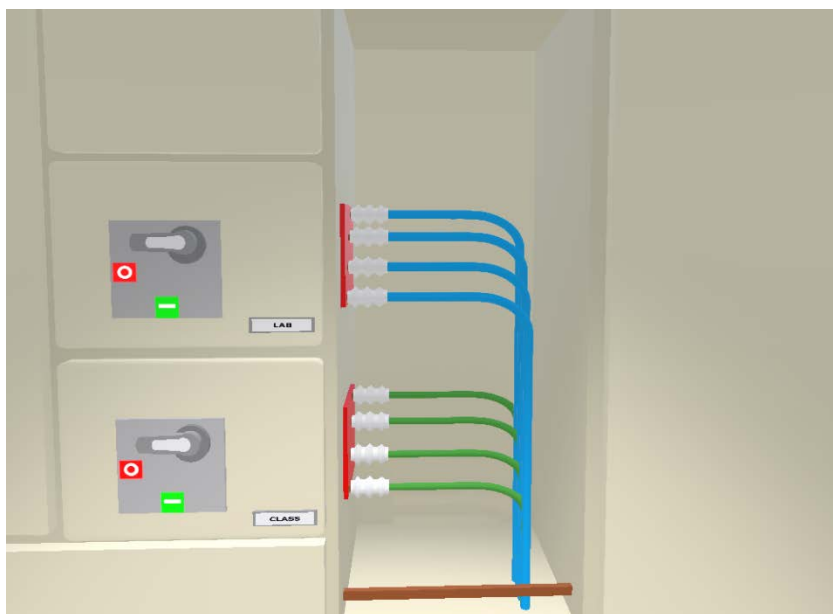


Figure 20: Switchboard with no backup power line and separators

- **Phase 1.** This phase is identical to the Phase 1 of the First scenario, but the voice-over welcomes the user to the Second scenario.
- **Phase 2.** The user opens the electrical switchboard and looks at the power lines. The voice-over tells that the user's task is to make measurements on a certain power line (as said, currently named 'Lab'). In this scenario, the enclosure has no backup line and plexiglass separators are not present.

Voice 3: "Your task in this simulation is to make power measurements on the line named 'Lab'. To identify the line, look at the labels placed near the electrical switches. Notice also the line named 'Class', placed below. To proceed, open the electrical switchboard door".

Voice 4: "Since there is no backup power line, you need the Personal Protective Equipment (or PPE) to protect you from electric shock. Since the enclosure has no plexiglass separator, you need also the PPE to protect you from electric arcs. You can find the PPE in the closet near the blue door. Locate it to proceed" (Figure 21).



Figure 21: Closet with the PPE

The user finds the closet in the scene.

Voice 5: "To protect you from electric shocks, take the protective gloves from the closet".

The user interacts with the gloves and the helmet.

Voice 6: "To protect you from electric arcs, take the helmet with the protective screen from the closet".

Voice 7: "Take also the protective plastic sheet from the closet and place it on the conductor of the power line named 'Class'".

Avoided errors:

- The user does not check the power line's name and makes wrong connections in the following phases. This error can be made or fixed also in the following phases.
 - The user does not select the PPE when needed or selects the wrong PPE. This error leads to a potentially fatal error in the following phases, but it can be fixed in any moment before a fatal error occurs.
- **Phase 3.** The user makes voltage connections on the instrument and the enclosure. Since there is no backup power line, the user must make the voltage connections directly on the active line named 'Lab'; the power line named 'Lab' is active, therefore the user shall not move the corresponding switch to 'Open'.

Voice 7: "Now it is time to make the necessary connections on the measuring instrument, so find it in the scene. Remind that the electrical probes must be plugged into the measuring instrument before connecting them to the conductors. To facilitate the next steps of the procedure, it may be useful to grab the measuring instrument or place it vertically on the stool with the upper part facing up".

Voice 8: "In the upper part of the measuring instrument you can find a total of twelve sockets".

Voice 9: "The sockets are organized in groups of three; each group can be used to make a measurement on a different phase".

Voice 10: "Each group consists of two sockets for the voltage connections (a colored one for the high value and a black one for the reference value) and a third socket for the current connection".

Voice 11: "Start with the voltage measurements. The crocodile clips have different colors to facilitate this operation: you should plug each crocodile clip into the socket of the same color. If you have problems during the following operations, put the measuring instrument vertically, with the sockets facing up".

Voice 12: "Take both ends of the red crocodile from the table and plug the jack into the red socket in the first group. Leave the crocodile near the instrument".

Voice 13: "Take both ends of a black crocodile from the table and plug the jack into the black socket, in the same group as before. Leave the crocodile near the instrument".

Voice 14: "You should proceed in the same way for the other clips, plugging each crocodile into the socket of the same color. For now, let's jump ahead to the next phase".

The screen fades to black and, after a brief pause, the other crocodile clips are automatically connected to the sockets.

Voice 15: "Now that all the crocodile clips are connected to the measuring instrument, you have to make the connections in the electrical switchboard. Since there is no backup power line, you must operate directly on the active power line named 'Lab'. The PPE will protect you from possible risks".

Voice 16: "The power line has four protective covers. Move them to expose the conductors".

Voice 17: "In this simulation, you will measure the value of the first three voltages".

Voice 18: “with respect to the fourth one (also called neutral),”.

Voice 19: “and the value of the neutral with respect to ground. You can find the ground in the lower part of the switchboard”.

Voice 20: “For each of the first three groups of sockets of the measuring instrument, connect the colored crocodile clips to one of the first three exposed conductors. Connect the red crocodile to the first conductor to measure the first voltage”.

Voice 21: “Connect the corresponding black crocodile to the fourth conductor”.

Voice 22: “Connect the yellow crocodile to the second conductor”.

Voice 23: “Connect the corresponding black crocodile to the fourth conductor”.

Voice 24: “Connect the blue crocodile to the third conductor”.

Voice 25: “Connect the corresponding black crocodile to the fourth conductor”.

Voice 26: “The fourth group of sockets must be used to measure the neutral with respect to ground. Connect the white crocodile to the fourth conductor”.

Voice 27: “Connect the corresponding black crocodile to the Ground conductor”.

The user makes the connections and can move to the next phase.

Avoided errors:

- The user makes the connections on the wrong power line.
 - The user makes voltage connections directly on the ‘Lab’ power line without the correct PPE.
 - The user makes the connections on the power line before making them on the instrument.
 - The user makes connections on the instrument while it is turned on.
 - The user gets too close (30 cm) or touches the power line while the corresponding switch is on ‘Closed’; touching the power line will lead to a fatal error.
 - The user makes the wrong connections (not using all the clips, using the sockets in a wrong way, etc.).
- **Phase 4.** This phase is identical to the Phase 4 of the First scenario.
 - **Phase 5.** This phase is identical to the Phase 5 of the First scenario, except for *Voice 37* (which is not needed in this scenario).

4.4 Evaluation

The user starts the simulation in the middle of the virtual room. In both the scenarios, a brief introduction describes the procedure and the user’s goal.

Voice 0: “This is the Evaluated mode of the simulation, in which you are free to move and interact with the virtual objects. Use the measuring instrument, the crocodile clips and the clamps to make the necessary connections on the cabinet in order to obtain the requested long-term measures. Once you are done, interact with the blue door to get your evaluation”.

The user is free to move in the room and to interact with the virtual objects. His or her goal is to set the instrument up in order to obtain long-term measurements. The user can interact with the blue door and leave the room to receive the final evaluation.

The user's actions are evaluated in different categories. Each category features a series of evaluation points and each point can take a positive, negative or neutral evaluation. The categories are described in the following.

- **Safety.** This category concerns safety regulations and consists of the points below.
 - **Distance from an active exposed conductor in unsafe conditions.** The final grade of this point is negative if the user's hands come close to an exposed conductor of an active power line without the proper PPE, otherwise the grade is positive.
 - **No contact with an active exposed conductor in unsafe conditions.** The final grade of this point is negative if the user's hands touch an exposed conductor of an active power line without the proper PPE, otherwise the grade is positive.
 - **No voltage connection on an active exposed conductor in unsafe conditions.** The final grade of this point is negative if the user makes a voltage connection on an exposed conductor of an active power line without the proper PPE, otherwise the grade is positive. The grade is neutral if the user does not make voltage connections.
 - **Probes connected first to the instrument.** The final grade of this point is neutral if the user leaves the virtual room without using the probes. The final grade is positive if all the used probes are connected first to the measuring instrument, negative if at least one probe is connected first to the switchboard.
 - **Warning sign placed.** The final grade is positive if the user places a warning sign to warn about the exposed conductors before leaving the room.
 - **Instrument turned off during connections.** The final grade of this point is neutral if the user leaves the virtual room without using the probes. The final grade is positive if all the used probes are connected to the measuring instrument while the instrument is turned off, otherwise the grade is negative.
 - **Switch tested (first scenario only).** The final grade is neutral if the user does not make voltage connections on an open circuit. If the user uses an open power line without PPE, the final grade is positive if the user checks the corresponding switch (first, he or she must turn it off, then use the tester to confirm that the voltage is null), otherwise it is negative.
 - **Plastic sheet placed (second scenario only).** The final grade is positive if the use places an insulating sheet over the power lines without a plexiglass separator.
- **Voltage connections.** This category concerns the voltage connections and consists of five points.
 - **All probes connected to the instrument.** The final grade of this point is negative if the user does not connect all the crocodile clips to the instrument.
 - **All probes connected to the switchboard.** The final grade of this point is negative if the user does not connect all the crocodile clips to the switchboard.
 - **Connections on target power line.** The final grade of this point is neutral if the user leaves the virtual room without using the probes. The grade is positive if all the connections are on the target power line, the backup power line and the Ground.

- **Measured power line switch on “close”.** The final grade is neutral if the user does not make connections on a power line. The grade is positive if the user makes connections on a power line and leaves the corresponding switch on “close” at the end of the simulation, otherwise the grade is negative.
- **“Lab” and “Class” switches left on “close”.** The power lines named ‘Class’ and ‘Lab’ are active and working: the final grade is negative if the user closes one of these switches during the simulation.
- **Current connections.** This category concerns the current connections and consists of six points (Figure 22).
 - **Right type.** The final grade of this point is neutral if the user leaves the virtual room without using the probes. It is positive if the user uses only probes of the correct type, otherwise the grade is negative.
 - **Right probes connected to the instrument.** The final grade is negative if the user does not connect all the right probes to the instrument.
 - **Right probes connected to the switchboard.** The final grade is negative if the user does not connect all the right probes to the switchboard.
 - **Right orientation.** The final grade of this point is neutral if the user leaves the virtual room without using the probes. The grade is positive if all the used probes have the right orientation (the arrow must point to the right), negative otherwise.
 - **Connections on “Lab” power line.** The final grade of this point is neutral if the user leaves the virtual room without using the probes. The grade is negative if the user makes connections on a power line different from the power line named ‘Lab’, positive otherwise.
 - **“Lab” power line switch on “close”.** The grade is positive if the ‘Lab’ power line switch is on ‘Close’ when the user leaves the room, otherwise the grade is negative.

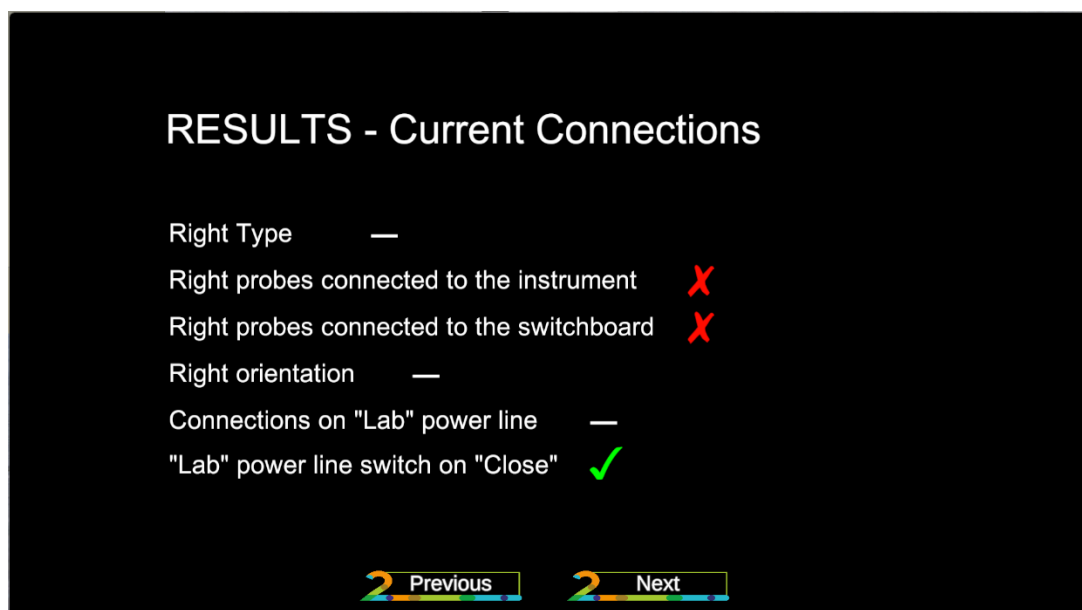


Figure 22: Final report, inside the application

- **Group of sockets.** This category concerns the logical use of the different groups of sockets of the measuring instrument. Each point gets a positive grade if the corresponding sockets are used according to the correct procedure. For the first three group of sockets:
 - the colored socket measures the value of a voltage and must be connected to the conductor of the phase X (with $0 < X < 4$) of a power line Y;
 - the black socket measures the value of a voltage and must be connected to the Neutral conductor of the power line Y;
 - the third socket measures the value of a current and must be connected to the cable of the same phase measured by the colored socket (phase X); the socket can be connected to a power line Z (with $Z \neq Y$) if Y is the backup power line and Z is the target power line (the one named 'Lab').

If any of these conditions is violated, the final grade is negative. In addition, in case two groups of sockets end up measuring the same phase, one of them will get a negative grade.

For the fourth group of sockets:

- the colored socket measures the value of a voltage and must be connected to the Neutral of power line Y;
- the black socket measures the value of a voltage and must be connected to the Ground;
- the third socket shall not be used.

If any of these conditions is violated, the final grade is negative.

This category consists of four points:

- **First group;**
- **Second group;**
- **Third group;**
- **Fourth group (Neutral).**

- **Measuring instrument.** This category concerns the use of the measuring instrument and consists of six points.
 - **Instrument turned on.** The final grade of this point is positive if the instrument is turned on at the end of the simulation, negative otherwise.
 - **Instrument on charge.** The final grade is positive if the instrument is on charge at the end of the simulation, negative otherwise.
 - **Right type of clamp selected.** The final grade is negative if the user does not select the type of clamp used or selects the wrong type of clamp (while setting up the measuring instrument).
 - **Sampling interval selected.** The final grade of this point is negative if the user does not set the sampling interval (while setting up the measuring instrument).
 - **Measuring period selected.** The final grade is negative if the user does not set the measuring period (while setting up the measuring instrument).
 - **Instrument started.** The final grade is positive if the user starts the measuring procedure on the instrument, before leaving the room.

The final report produced by this mode (Figure 23) is saved in the application folder, under the path “\E2DRIVER_Data\Saves”. Its structure is as follows:

- The name of the file is generated automatically and it is composed by the date and the hour of the evaluation ("*mm dd yyyy hh mm ss*", where *mm* is the month expressed on two digits, *dd* the day expressed on two digits, *yyyy* the year expressed on four digits, *hh* the hour expressed on two digits, *mm* the minutes expressed on two digits, *ss* the seconds expressed on two digits).
- The file starts with the word "**REPORT**" followed by two empty lines.
- The report is composed by the evaluation of the five different categories (Safety, Voltage connections, Current connections, Groups of sockets, Measuring instrument). The categories have different length (number of evaluated points), therefore a special character is used to identify the start of a new category. In particular, each category begins with "***_Name of the category***" (e.g., "***_Current Connections***"), followed by an empty line.
- For each category, all the evaluated points are listed with the format "***Description of the point _ evaluation mark***", where "***_***" is the special symbol separating the name from the grade, and the grade is either "***-***", "***X***" or "***V***" (i.e., neutral, negative or positive, respectively).

```

_Current Connections

Right Type _ -

Right probes connected to the instrument _ X

Right probes connected to the switchboard _ X

Right orientation _ -

Connections on "Lab" power line _ -

"Lab" power line switch on "Close" _ V

_Group of Sockets|

```

Figure 23: Final report, saved version (detail)

5 TRAINING PROTOCOL

In this chapter, a possible way to use E2DRIVER application for training is described.

5.1 Overview

In Chapter 2 it is mentioned that immersive VR applications are commonly and successfully used as training instruments. These applications are exploited to train medical operators, pilots, drivers, soldiers, first responders, and all the workers or volunteers that must be prepared to act in dangerous or hardly replicable situations.

Even through immersive technologies are getting quite common today, their use for training purposes is not standardized yet. The existing applications are generally not developed following a framework, and the final structure of the VR simulation depends on the target and the domain for which the simulation itself was actually developed. All these factors imply that, for now:

- for each new simulation, it is necessary to define the procedure that must be followed in order to use the developed application as a training instrument;
- for each new simulation, both the quality of the application and the effectiveness of the training need to be tested.

5.2 Procedure

The E2DRIVER application has been designed as a two-step training instrument. For each scenario, the trainees are expected, in principle, to:

- use the Guided mode as a training ground to study and learn the procedure;
- then use the corresponding Evaluated mode to test their knowledge. The final report produced by this mode should then be used by the trainees to understand the mistakes made, and by the trainers to know their performance level.

In order to test the quality of the application and the validity of the proposed two-steps procedure, it is recommended to consider a set of guidelines and follow a series of steps when the E2DRIVER training session will take place, as reported below.

- The users who test the application should have no previous knowledge of application itself (it should be the first time that they see or try any material related to the VR simulation).
- The users should read the Pre-training presentation (Annex A) before the training session (<https://www.dropbox.com/sh/9mc9m4eysu06t0e/AAD4iSc18MhJDoSoVsz0drG2a>).
- The users should choose a scenario (for the sake of comparing performance, all the users should select the same scenario, being the First scenario the recommended one) and experience, in order, the Guided mode and the Evaluated mode for it. The order is important: the Evaluated mode must be experienced after the Guided mode. The overall time to complete both the modes for one scenario should be approximately 15+15 minutes per user. It is recommended to take a brief pause between the two modes.
- It is possible to pause the simulation, but it is recommended to complete both the modes. If a user needs to pause the experience, he or she can remove the HMD. He or she can then continue the simulation from where he or she left it.

- To evaluate the experience, the user could fill in the VR training questionnaire (Annex B). Questionnaire (<https://www.dropbox.com/sh/9mc9m4eysu06t0e/AAD4iSc18MhJDoSoVsz0drG2a>) is organized in four parts: a preliminary one to be filled in before the training with general information by the participant, one addressing the Guided mode, one addressing the Evaluated mode and one addressing the whole training experience.
- Should available time be not enough to go through the whole experience, the user may be invited to experience only the Guided mode (in this case skipping questions concerning the other mode in the VR training questionnaire).
- During the simulation, it is possible to experience sickness. If the sickness is too strong, it is recommended to interrupt the experience. It is possible to report and rate the experienced sickness in the VR training questionnaire.
- Compiled questionnaires, along with the corresponding final report, should be collected for further processing.

5.3 Questionnaire

The VR training questionnaire is a collection of questions to be answered by the trainees aimed to evaluate the E2DRIVER application, the Guided mode, the Evaluated mode and the whole VR training experience. It is paired with a form (Annex C) in which the training administrator will take note of the selected scenario and, for each experienced training mode, will record the start time, the end time and whether the simulation had to be paused (with the corresponding total pause duration). The questionnaire is not mandatory, but it could be used to get insights on the VR experience. *No sensible, personal data is collected.* The questionnaire is composed of four parts.

- The first part encompasses questions about user's demographics and previous experience, as well on pre-existing sickness (the user should state if he or she suffers of pre-existing conditions like headache, stomachache). This part should be compiled before the VR experience.
- The second part encompasses questions about the quality of the guiding system and the user's health status after the experience (to understand if the user developed new symptoms), and should be compiled right after the user finished the Guided mode (before starting the Evaluated mode).
- The third part encompasses questions on the quality and the appropriateness of the evaluation system, as well as about the user's health (to understand if the user developed new symptoms), and should be compiled right after the user finished the Evaluated mode (if actually experienced).
- The fourth part should be compiled at the end of the VR experience (after the user completed the experience with at least the Guided mode). It encompasses questions about:
 - accuracy of the simulation;
 - quality and effectiveness of the interface;
 - quality and effectiveness of the interactions;
 - immersion and presence;
 - quality of the experience;
 - usability;
 - effectiveness/potential of the proposed training procedure.

6 USER MANUAL

In this chapter, it is possible to find all the steps to be executed in order to run the VR simulation on a PC. The first section presents the hardware and software required to run the application; the second section describes the procedure to use the said hardware and software; finally, the third section offers a quick guide on the simulation menu and the interactions allowed in the virtual environment.

6.1 Requirements

The use of an immersive, interactive VR application puts some constraints on the hardware.

Since the simulation is not designed to be run as a desktop application, an HMD is required. Among the possibilities, it is recommended to use an HTC Vive Pro (Oculus Quest or Oculus Rift S are valid alternatives). To use an HMD, it is necessary to use a PC with a fast CPU and a powerful GPU. In general, the minimum requirements for VR are a CPU Intel Core i5-4590 or AMD FX 8350 (equivalent or better) and a GPU NVIDIA GeForce GTX 970 or AMD Radeon R9 290 (equivalent or better), mounted on a PC with 4GB of RAM (minimum), Broadband Internet connection and the necessary ports to connect the HMD to the PC. The general recommended requirements, instead, suggest a GPU NVIDIA GeForce GTX 1060 or AMD Radeon RX 480 (equivalent or better).

The minimum and recommended requirements are the ones needed to run SteamVR, a third-party application used during the development and required to run the developed VR application. It is possible to download the SteamVR application from the Steam Store (an account is necessary, but the program is free).

During the development and the testing of the application, it was noticed that the minimum requirements were not enough to run the application smoothly; therefore, it was decided to change the requirements and to make them stricter.

The updated **requirements to run the E2DRIVER VR application (not considering a particular HMD)** are described in Table 3.

Table 3: Requirements of the PC for running the VR application, not considering the HMD

Requirements		
Parameter	Minimum requirements	Recommended requirements
Operating System	Windows 10	-
Processor	Intel Core i7	-
Memory	8 GB RAM	16 GB RAM
Graphics	GPU NVIDIA GeForce GTX 1060 (equivalent or better)	GPU NVIDIA GeForce RTX 2070 (equivalent or better)
Network	Broadband Internet connection	-
Additional notes	Necessary ports for the HMD	-

Depending on the HMD, the proper number of ports to connect it to the PC (and to connect the VR sensors) **is required** (along with several electrical sockets). The HTC Vive Pro, for example, must be connected to the PC using a DisplayPort 1.2 (or newer, Figure 24) and a USB 3.0 (or newer). It is important to notice that the HMD must be connected to the DisplayPort of the GPU. If there is no

DisplayPort, it is possible to connect the HMD using a MiniDisplayPort or USB-C port that is DisplayPort 1.2+ compatible. The HTC Vive Pro requires also an electrical socket for the HMD and two electrical sockets for the two sensors (called Base Stations, Figure 25).



Figure 24: DisplayPort



Figure 25: HTC Vive Pro – Base Station

The **final requirements in case the HMD used is the HTC Vive Pro** are described in Table 4.

Table 4: Requirements of the PC for using it with the HTC Vive Pro HMD

Requirements		
Parameter	Minimum requirements	Recommended requirements
Operating System	Windows 10	-
Processor	Intel Core i7	-
Memory	8 GB RAM	16 GB RAM
Graphics	GPU NVIDIA GeForce GTX 1060 (equivalent or better)	GPU NVIDIA GeForce RTX 2070 (equivalent or better)
Network	Broadband Internet connection	-
Additional notes	USB 3.0; DisplayPort 1.2 (or newer)/MiniDisplayPort 1.2/USB-C port (DisplayPort 1.2+ compatible)	-

6.2 Installation

To install the HTC Vive Pro it is necessary to follow the basics steps reported below.

- Find a large free space (the minimum is 2m × 1.5m, but a 3m × 4m or larger area is recommended, since it would be similar in size to the room of the simulation) with no window (if there are windows, it is better to cover them) and with no reflecting surfaces; the Vive Pro uses optic sensors, therefore sunlight and reflections can disturb the signal.
- Install the Base Stations at two opposite corners of the area. For optimal tracking, make sure that the maximum distance between the two Base Stations is 5m. They must be elevated and slightly angled to point towards the ground, while still “seeing” each other.
- Download ViveSetup.exe [3] and launch it.
- Download Steam, create a Steam Account and download SteamVR.
- Update the Graphics Card Drivers to the latest version.
- Check that the Base Stations are set up and running. Both the light on the stations and the icons of the stations in SteamVR must be green.
- Connect, in order, the USB 3.0 cable, the DisplayPort cable and the Power cable to the Link Box (Figure 26). Connect the other end of the power cable to a power outlet.



Figure 26: HTC Vive Pro – Link Box

- Connect the other end of the USB 3.0 cable to a USB port on the PC, then connect the other end of the DisplayPort cable to a DisplayPort 1.2 (or higher) on the graphics card. The DisplayPort cable must be connected to the same graphics card connected to the monitor.
- Connect the headset cable to the Link Box, then press the power button on the Link Box.
- Pair the hand controllers. Turn on the controllers and launch SteamVR. On the SteamVR interface there are 5 icons. Three should be green (the ones corresponding to the headset and the stations) and two should be gray (the ones corresponding to the controllers). Right-click on one of the controller icons, then select Pair controller and follow the instructions. Repeat the process for the other controller.
- From the SteamVR menu, select Room Setup and follow the instructions to set up a room-scale virtual room.
- Download the VR application, unzip the archive and open the folder. Launch the E2DRIVER application to start the simulation.

6.3 Instructions

The E2DRIVER application starts with a desktop menu. The first page encompasses a warning about the safety practices and requirements needed to perform the measuring procedure on real equipment. The user must read and confirm to have understood the warning by clicking on the “I accept” button to proceed with the simulation. The menu must be navigated using the mouse; therefore, it is recommended to wear the HMD after the simulation has been configured and has been started. From the “Starting page” of the menu (Figure 27), it is possible to choose the simulation language and the scenario. The “Language” button leads the user to a page that offers different language options; once the user has chosen the desired language, he or she must go back to the previous page to continue the configuration. The “Scenario” button leads the user to the selection of the scenario.

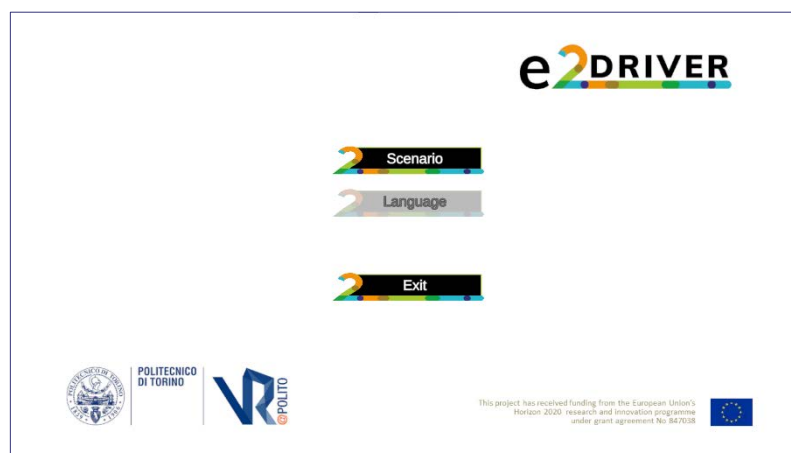


Figure 27: Main menu - Starting page

From the “Scenario page” (Figure 28) it is possible to select the scenario of the simulation. The user can choose “Scenario 1” to follow a measurement procedure on an electrical switchboard with a backup power line and plexiglass separators, or “Scenario 2” to make measurements on a switchboard without backup power line and plexiglass separators.

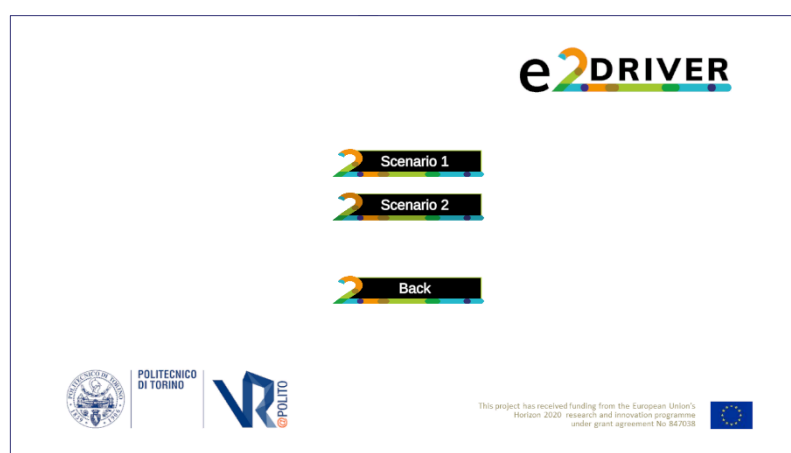


Figure 28: Main menu - Scenario page

The choice of the scenario leads the user to the “Mode page” (Figure 29), where he or she can choose the type of simulation. In “Guided mode”, the user must follow a series of instructions narrated by a voice-over, whereas in “Evaluated mode” the user is free to interact with the virtual world.

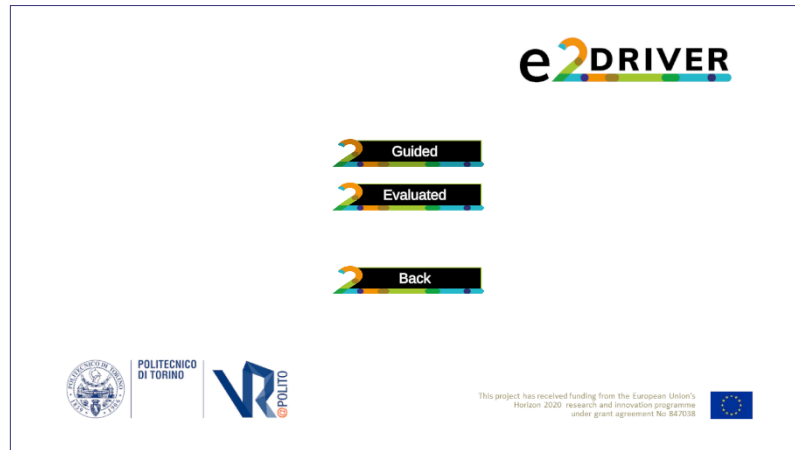


Figure 29: Main menu - Mode page

The choice of the mode leads the user to a page with a “Start” button. After pressing the button, it is possible to wear the HMD, grab the controllers and start the simulation.

In the simulation, the user can look around and move freely. Since the HMD is tracked, actions like turning the head, crouching and moving are mapped and translated directly in the virtual room (for example, if the user turn his or her head to the right in the real world, the same happens in the virtual room). Since the real area where the user is located can be limited, the movement is constrained: if the user moves away from the center of the area and towards its boundaries, a 3D grid appears in the virtual world to keep the user safe. If the grid is visible, it is recommended to move towards the center of the area, until the grid disappears. Since fully constraining the movement of the user would have hurt the whole VR experience, a secondary movement method (based on the hand controllers) has been added to the simulation.

The controllers (Figure 30) are the main way to interact with the virtual world. They are visible inside the virtual environment and they offer a series of buttons that can be used to interact with virtual objects. In particular, in this simulation, controllers are exploited as reported below.



Figure 30: HTC Vive Pro - Controller

- The Grip button is used to move in the virtual room. Holding both the controllers and pressing the Grip buttons with the middle fingers, it is possible to swing the arms back and forth towards a desired position to move in the corresponding direction. This method of locomotion is called *arm swinging*, and it is used when the virtual world size exceeds the free real area where the user is located.
- The Trigger button is used to interact with the virtual objects. Inside the simulation, the user can place the controllers near an object; if an interaction is possible, the object is highlighted (with a blue outline for the 3D objects, with a green one for the buttons of the measuring instrument interface). If the button is pressed, the interaction is triggered. There are two types of interactions, described below.
 - Object activation. Pressing the Trigger button activates an action on an object (open/close a switch, open/close a door, wear/remove PPE, press a button, etc.).
 - Grabbing/Dropping an object. Pressing the Trigger button places an object in the virtual hand of the user. Pressing the button again, while an object is grabbed, releases the object in the scene. It is possible to grab an object with each hand and to grab an object held by the other hand.
- The Teleport button is used in the Guided mode to repeat the last instruction narrated by the voice-over (only if the voice-over is not active in that moment).

All the described buttons are active on both the controllers (Figure 31).

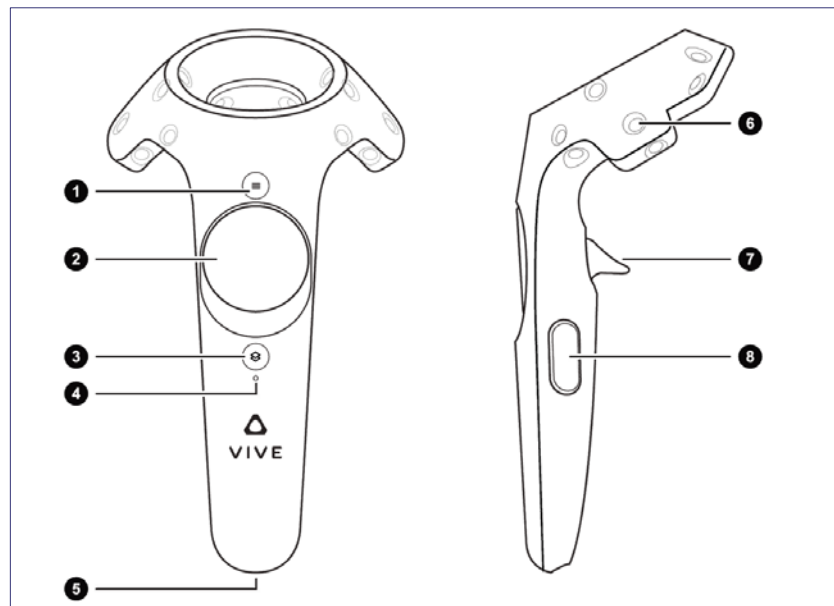


Figure 31: HTC Vive controllers - Teleport (2), Trigger (7), Grip (8)

Depending on the mode of the simulation, certain interactions may be unavailable.

- In the Evaluated mode, the Teleport button is not used, since there are no instructions to follow.
- In the Guided mode, the user must follow the instructions. Certain interactions are not available until the corresponding instruction has been played. An instruction is considered “played” only when the voice-over stop talking, therefore the user must wait for the end of the instruction in order to perform the corresponding action. In case of an action that involves a 3D object, the corresponding object will blink in red, and the blinking will stop once the user touches the object (if the instruction says to interact or grab an object) or once the user finds the object in the scene. In case of an action that involves two objects, both the objects will blink in red. If a grabbed object must interact with a blinking one, a green blink will notify a correct action or position (Figure 32).

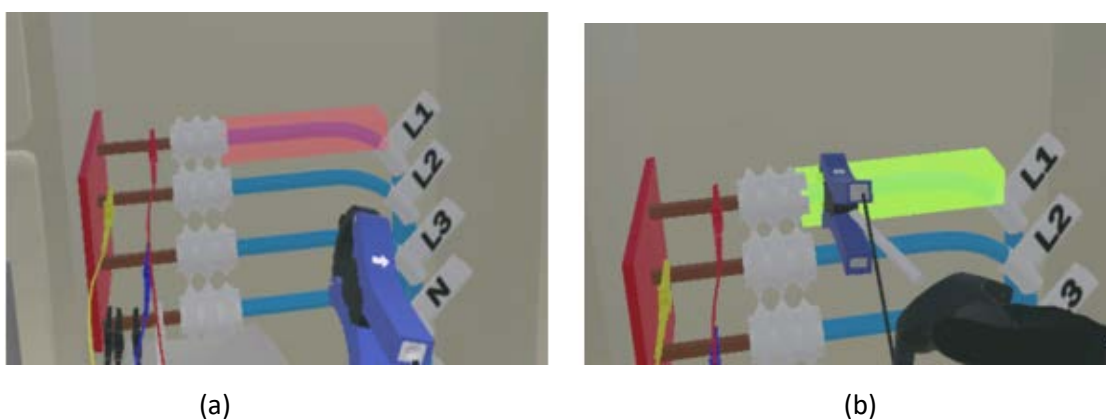


Figure 32: Objects blinking: the clip is too far (a) and in the right position (b)

7 CONCLUSIONS

This document presented an application that has been developed as part of the training material accessible through the E2DRIVER platform, supporting more theoretical content with practical, hands-on exercises that can be carried out in a 3D environment.

Particular care has been devoted to faithfully reproduce the various operations to be performed in a measuring procedure, as well as the underlying safety aspects. Two scenarios engaging the users in different experiences and two modes, letting them operate in a guided, step-by-step way or autonomously (for the purpose of being evaluated on the said operations) have been implemented.

The use of immersive VR technology is expected to enhance the user experience, but in the future a desktop version of the application could be created in order to use it also in other settings. In fact, the application was originally devised for non-formal learning contexts addressed by the E2DRIVER project, but having it available also in non-immersive environments (common PCs, smartphones, etc.) would allow it to be transported and tested in formal contexts (e.g., university classes) to further study the degree of transferability of the proposed training method.

REFERENCES

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- [2] Dranetz PowerGuide® 4400 – User’s Guide, <https://www.dranetz.com/wp-content/uploads/2014/02/PG4400-UsersGuide-RevJ.pdf>
- [3] HTC Vive – Vive Setup <https://www.vive.com/sea/setup/vive-pro-hmd/>



ANNEXES

Annex A: Pre-training Presentation

Document's link: <https://www.dropbox.com/sh/9mc9m4eysu06t0e/AAD4iSc18MhJDoSoVsz0drG2a>




VR Application: Training goal


- Learn how to perform measurements on *electric cabinets* in a simulated, virtual scenario mimicking a real one
- Elements that have been recreated in the virtual experience (e.g., the measuring instrument, etc.) shall be regarded as possible *proxies* of more generic physical elements that one could found in real settings

Pre-training presentation 3

VR Application: Hardware




- VR kit: HTC Vive Pro (shown) or equivalent devices, and a VR-ready PC
 - Head-mounted Display (HMD), or headset: to get a stereoscopic view of the virtual environment
 - Hand controllers (recreated in VR): to interact with the virtual environment and objects in it



Pre-training presentation 4


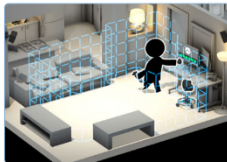
VR Application: Basic interactions



- Two types of basic *interactions*
 - Movement (locomotion)
 - Object activation (and use)

Pre-training presentation 5

Movement (1)


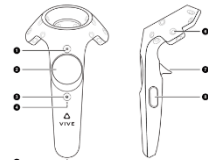



https://support.steampowered.com/steam/hitc_vive/

- Physical movement in the virtual room boundaries (depending on physical space available)
 - Safe area delimited by a virtual grid, appearing when getting close to set boundaries

Pre-training presentation 6

Movement (2)






* Button numbering is that of HTC Vive controllers

- Virtual movement (*arm swinging*) always possible
 - Obtained by keeping the Grip button (8) of one or both the controllers pressed and swinging at the same time the arms back and forth towards the desired position

Pre-training presentation 7

Object activation (1)

- Interactive objects highlighted by outlines when touched with one of the controllers
 - Blue for 3D objects
 - Green for buttons

Pre-training presentation 8

Object activation (2)

- Interaction activated by pressing the Trigger button (7)
- Possible outcomes:
 - Object grabbed
 - Instrument turned on
 - Switch opened
 - ...

* Button numbering is that of HTC Vive controllers

Pre-training presentation 9

Object activation (3)

- When grabbed
 - Objects are bound (remain attached) to the corresponding controller
 - Can be dropped by pressing the Trigger button (7)
 - Can be grabbed with the other controller, e.g., to pass the object from one hand to the other hand

* Button numbering is that of HTC Vive controllers

Pre-training presentation 10

Object activation (4)

- When dropped near certain objects, new interactions become possible
- Examples:
 - Inserting a jack into a socket
 - Placing a clamp on a cable
 - ...

Pre-training presentation 11

VR Application: Scenarios

- Two interactive *scenarios*
 - Scenario 1*: With a backup power line and plexiglass separators
 - Scenario 2*: With no backup power line and plexiglass separators (hence requiring PPE for the whole duration of the measurement task)
- The simulation illustrates the user when PPE is needed (and why), and require him or her them to wear it

Pre-training presentation 12

VR Application: Scenarios

- Before starting the experience, the following warning is displayed
 - This application was developed following the guidelines in European Standard EN 50110-1 "Operation of electrical installations - Part 1: General requirement" and in IEC 61243-3:2014. The intent of the application is to present measurement operations implying diverse safety requirements. Before performing these operations on real equipment, it is strictly required to complete a training about occupational risk prevention to become a person adequately advised or supervised by electrically skilled persons or with relevant education and experience to perceive risks and to avoid hazards which electricity can create, as well as to fulfill the proper EU or national requirements. These instructions are not included in this E2DRIVER training application, which has the aim of showing the process in a virtual way that is intrinsically "safe".

Pre-training presentation 13

VR Application: Training modes

- Two training *modes* for each scenario
 - Guided mode*: to learn the procedure
 - Evaluated mode*: to assess the users' knowledge of the procedure and performance on executing it

Pre-training presentation 14

Guided mode (1)

- Series of instructions given by a voice-over
 - Explaining the procedure
 - Describing the action to perform (grab an object, look at an object, etc.)
- Instructions can be repeated by pressing the Touchpad (2)

* Button numbering is that of HTC Vive controllers

Pre-training presentation 15

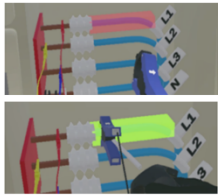
Guided mode (2)

- Relevant objects
 - Are highlighted and blink
 - Become interactable once the instruction about them has been given
- Non-relevant objects
 - Are non-interactable

Pre-training presentation 16

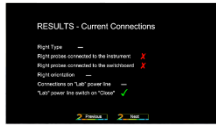
Guided mode (3)

- Blinks
 - Are timed with the instructions
 - Red blinks highlight objects that are relevant for the experience, as the user needs to interact with them
 - Green blinks indicate correct interactions involving multiple objects (e.g. a cable and a clamp)



Pre-training presentation 17

Evaluated mode



- Movement interactions are free
- User's actions are tracked
- Evaluation report for user's assessment
 - Generated when the user interact with the blue door to exit the scene (and simulation ends)

Pre-training presentation 18

Training procedure

- Read the Pre-training presentation (this file)
- Fill in Part 1 of the "VR training questionnaire"
- Experience Scenario X* in Guided mode (10-15 min)
- Fill in Part 2 of the "VR training questionnaire"
- Experience Scenario X* in Evaluated mode (10-15 min, if enough time)
Receive the evaluation report generated by the application
- Fill in Part 3 and Part 4 of the "VR training questionnaire"

* Scenario 1 recommended (same for 3 and 5) since it is shorter than Scenario 2. Experience can then repeated with the other scenario.
* Filling in the "VR training questionnaire" is helpful to support the assessment of the VR training experience, but not mandatory

Pre-training presentation 19

In case of sickness

- Pause the application
 - It is sufficient to remove the headset
 - It is possible to resume the application wearing it again
- If the sickness is too strong, interrupt the experience
 - Fill in the "VR Questionnaire", if possible
 - Interruption in Guided mode: fill in Part 1, 2 and 4
 - Interruption in Evaluated mode: fill in Part 1, 2, 3, 4

Pre-training presentation 20

Thank you for your participation!



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Annex B: VR Training Questionnaire

Document's link: <https://www.dropbox.com/sh/9mc9m4eysu06t0e/AAD4iSc18MhJDoSoVsz0drG2a>

VR Training Questionnaire

I agree to participate in this training. I understand that participation is voluntary and I agree to immediately raise any concerns or areas of discomfort during the session with the training administrator.

☐ Check here to indicate that you have read and you understand the information on this form and that any questions you might have about the session have been answered.

Part 1: Before the training

Company: _____ Training session ID: _____

1) How often do you use Virtual Reality systems such as HTC-VIVE Pro, Oculus Quest, Cardboard, etc.?

☐ never ☐ very rarely ☐ sometimes ☐ often ☐ very often

2) What is your familiarity with electric measurement procedures and related equipment?

☐ none (never made/used) ☐ little ☐ average ☐ high ☐ very high

3) Have you ever undergone a training on electric measurement procedures on electric cabinets?

☐ No ☐ Yes, specify: _____

Sickness: List any pre-existing condition, if present (e.g., headache, stomachache, eye pain, etc.)

Part 2: After the Guided mode

4) Have you completed this training mode?

☐ Yes ☐ No, because _____

Sickness: List any new condition, if present (e.g., headache, stomachache, eye pain, etc.)

Attention: Rate each statement on a scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

5) The quality of information/instructions helped to hold my attention	
6) The training was so abstract that it was difficult to hold my attention	
7) The way the information was provided helped keep my attention	
8) The amount of information provided was so large that the training was irritating	

Relevance: Rate each statement in a scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

9) The amount of information provided was so large that it was difficult to identify the most relevant to be remember	
10) The information provided by the voice-over gave me the feeling that the contents were worth learning	

Confidence: Rate each statement in a scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

11) In this training mode, I was confident that I would have been able to learn the taught contents	
12) In this training mode, I was confident that I would have been able to pass a test on taught contents	
13) I wasn't able to understand a significant portion of the training	
14) The (good) organization of contents supported my awareness on the fact that I would be able to learn them	

Satisfaction: Rate each statement in a scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

15) This training mode was too long	
16) I am overall satisfied with this training mode	

Part 3: After the Evaluated mode

17) Have you completed this training mode?

☐ Yes ☐ No, because _____

Sickness: List any new condition, if present (e.g., headache, stomachache, eye pain, etc.)

Miscellaneous: Rate each statement on a scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

18) I felt confident while performing the measuring procedure without a guide	
19) I felt the need to frequently stop throughout the measuring procedure to remember what should have to be done next	
20) The final report was coherent with my performance during this training mode	

Part 4: At the end of the whole experience

Usability Factor 1. Functionality: The interface should be able to provide the level of functionality (control) the user expects in order to perform a given task. The interface should not be ambiguous, it should be easy to learn, remember and access all the available functions, as well as to understand their meaning.

21) I would rate the VR system in terms of functionality as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 2. System input: The input device (the hand controllers, in this case) used to access

the system should be easy to use. Responsiveness and sensitivity should be appropriate for the task, and ideal for interacting with the virtual environment (for moving in the virtual space, for interacting with objects, etc.).

22) I would rate the system input as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 3. System output: Providing users with visual feedback in a VR system is extremely important. Video output should have the appropriate quality (e.g., in terms of resolution, lack of glitches, etc.), objects should appear as three-dimensional (sense of depth), and information displayed should be unambiguous and deliver all the necessary information to complete the task.

23) Overall, I would rate the output system as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 4. Consistency: The VR system should behave in the manner the user actually expects. It should be easy to understand the operation of the interface, which should behave in a consistent way.

24) Overall, I would rate the consistency of the system as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 5. Flexibility: The flexibility of the interface is a function of its intuitiveness and learnability. It should be easy for the user to perform the task in the order chosen, without interfering with the way he or she wanted to interact with the system.

25) I would rate the flexibility provided by the system as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 6. Simulation fidelity: The simulation underlying the VR experience should have the level of accuracy and quality required to be effective/to be of help. It should behave in the expected manner, with content recreated with proper fidelity so that the user does not feel disoriented during the experience.

26) I would rate the fidelity of the simulation as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 7. Robustness to errors (error correction/handling): The interface should be able to prevent the user from making mistakes while interacting with the system and should let him or her recover from them.

27) I would rate system robustness to errors as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

Usability Factor 8. Sense of immersion/presence: An important characteristic of a VR system is the sense of immersion (thanks to the sensory stimulation provided by the hardware used) and the sense of presence (that is, the impression of “being there”, of “feeling part of something that is really happening”) one gets.

28) I would rate my sense of immersion and presence as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

9 Overall system usability: This item investigates the user’s overall opinion of the system from the perspective of its usability, i.e., its intuitiveness and ease of use.

29) I would rate the system usability as:

☐ very unsatisfactory ☐ unsatisfactory ☐ neutral ☐ satisfactory ☐ very satisfactory

10 Effectiveness: Rate the following statement in a scale from 1 (*Strongly disagree*) to 5 (*Strongly agree*).

30) I think that VR is a valuable approach to training	
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11 Negative and positive aspects: List three negative and positive aspects of the VR system and the training experience, overall.

Negative aspects	Positive aspects

Other comments (if any)

Annex C: VR Training (Trainer form)

VR Training (Trainer form)

The study administrator will take note of the scenario selected for this training session, and for each experienced training mode, will record in the following table the start time, the end time, and whether the simulation has been paused (with the corresponding total pause duration).

Company: _____ Training session ID: _____

Selected scenario: ☐ 1 ☐ 2

Training time: _____

	Start time (hh:mm)	End time (hh:mm)	Pause duration (hh:mm)
Guided mode			
Evaluated mode			

Selected scenario: ☐ 1 ☐ 2

Training time: _____

	Start time (hh:mm)	End time (hh:mm)	Pause duration (hh:mm)
Guided mode			
Evaluated mode			