

# Virtual Reality System For Training Of Operators Of Power Live Lines

Israel Galvan, Andres Ayala, Javier Muñoz, Marco Salgado, Eric Rodríguez and Miguel Pérez

**Abstract— This article presents a training system for live-line operators of power distribution system. The developed training system is based on non-immersive virtual reality. The training is focused on the maintenance of high power live-lines in a distribution system. Most work in power systems must be free of interruption, so it is carried out by live-line techniques. However, these techniques have increased the number of accidents by electric shock. Because most electric accidents are due to live-line work, it is important to train live-line operators. The proposed training system provides repeated and cost-effective training for a small space. It also guarantees safety during training operations. This article, describes the architecture of the developed system, the creation of the virtual work environment, and the collision detection among virtual objects are also described. The system is currently training thousands of live-line operators from the 13 divisions of distribution system of the Mexican electric utility company. The general aim of our work is to provide operators of complex industrial environments with a suitable training to certify operators in knowledge, skills, expertise, abilities and attitudes for operation of power systems.**

**Index Terms— Training systems, virtual reality systems, power systems, industrial application.**

## I. INTRODUCTION

Electricity has become an essential element in the modern society, supporting the cultural and industrial development. The electricity utilities are responsible for generating, transmitting and distributing electricity to users. To meet this objective must have an efficient operation and maintenance. Electricity distribution is carried out by means of power lines. The reliable operation of the electricity distribution depends largely on adequate and timely inspection and maintenance of power lines; these are risky activities that currently are performed by power line operators, which should be well trained in order to reduce risks and prevent damage to

equipment and people. The accidents involving high-voltage power lines can be lethal.

Training of power line operators is an important problem faced by distribution power systems: updating knowledge and skills. For safety reasons it is not recommend to train operators in this dangerous environments. Hence, power line operators need to train in a simulated work environment, which should be as realistic as possible. The training requirements ask for powerful interfaces, a more efficient and personalized training by means of incorporating artificial intelligent (AI) techniques, adaptive interfaces, simulation tools, multimedia, and virtual reality components.

The application of Virtual Reality Systems in training processes has been shown as an interesting technology [1,2,3] in the industry environment. VR technologies try to provide realistic representations of the real world, so they are shown as a cheaper solution to currently training. The use of Computer Aided Design (CAD) has become generalized in the industrial environment last years. This implies that 3D models are available and so, a lot of work is ready in order to build VR environments. For these reasons, Interactive 3D representation of the actual work seems to be a natural learning media with characteristics that plain documents, blueprints, and fixed videos do not supply. The VR environment can provide simulation facilities, allows the trainee to interact with the system in a realistic way, even in abnormal operation and emergencies.

This paper describes the architecture and development of a Virtual Reality Training System for training of knowledge and skills of live-line operators. The system was developed for the learning of 20 maneuvers of high-voltage. The models of equipment, materials and tools were built to scale. Currently, the VRTS uses technology of no-immersive virtual reality. In contrast with a traditional training system, the main goal of the VRTS is to certify operators in knowledge, skills, expertise, abilities and attitudes for the maintenance and operation of live-line operators.

## II. LIVE-LINE MAINTENANCE

Live-line maintenance mainly deals with the maintenance of an energized line without any interruption to the power line. Live-line maintenance techniques for overhead power lines can be grouped into three classes: hot stick, bare hand, and rubber glove and barrier methods. In the hot stick method, the worker performs live-line work using different kinds of insulated hot sticks, with the worker maintaining the minimum approach distance from energized parts. In the bare hand method, the worker performs live-line work after the electric potential of the workers is equal to that of the energized parts. Workers can access the components by

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Israel Galvan Bobadilla is with the Instituto de Investigaciones Electricas, 62490 Cuernavaca, Morelos, Mexico (Phone: 52 777 3623820; fax: 52 777 3189854; e-mail: [igalvan@iie.org.mx](mailto:igalvan@iie.org.mx)).

Andres Ayala and Javier Muñoz is with the Instituto de Investigaciones Electricas (e-mail: [ayala@iie.org.mx](mailto:ayala@iie.org.mx))

Marco Salgado, Eric Rodriguez and Miguel Pérez is with the Instituto de Investigaciones Electricas (e-mail: [masm@iie.org.mx](mailto:masm@iie.org.mx), [erg@iie.org.mx](mailto:erg@iie.org.mx), [mperez@iie.org.mx](mailto:mperez@iie.org.mx) )

insulated ladders, insulated boom, cranes, or helicopters. The bare hand workers must wear a conductive suit composed of pants, jackets, socks, and gloves made from a cotton, asbestos, and stainless steel thread to shield them from the electric field. Generally, the bare hand work is conducted on energized transmission lines.

In the rubber glove and barrier method, the worker is fully insulated from energized parts with the approved rubber gloves and sleeves rated for the voltage and insulating work platform. The worker can get to the worksite using an insulated ladder or insulated bucket truck and carry out the work on a charged line with his or her hands. Generally, the live-line replacement work, which is the focus of the training, is based on the rubber glove and barrier method. The workers can touch energized parts wearing their rubber gloves, but the most energized components in the work area should be insulated for safety. The replacement work fuse holder operation must be performed by using a telescoping disconnect stick as a kind of hot stick at a safe distance to prevent harm due to electric spark.



**Figure 1. Some examples of maneuvers for live-line maintenance.**

The steps required to perform the maneuvers vary according to four main factors:

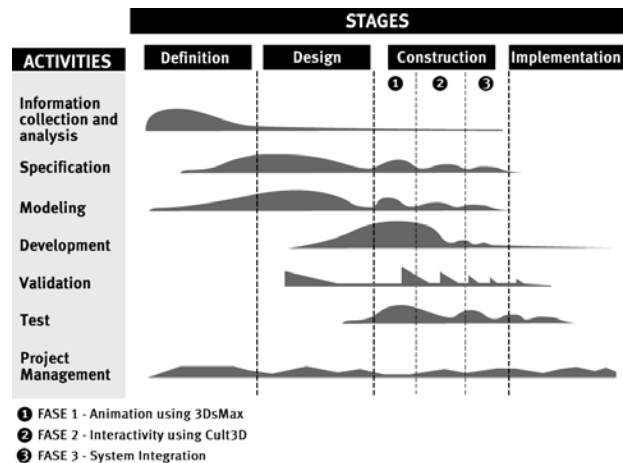
1. The type and configuration of the structure. In distribution networks, there are 3 types of structures: Type I poles (either wood or concrete), the steel towers and poles drogue.
2. The technique of maintenance. This can be using poles or with bare hands with security clothing.

3. The equipment for climbing. Most often, the operators climbing the structure through of its ladders or ropes, another option is to climb with crane basket or by helicopter
4. Different tools. The same maneuver can be performed with different tools

In conclusion, these kinds of maneuvers are dangerous and very varied, for example, the change of isolation in a steel tower in suspension can be performed with poles, climbing through the structure or using a yoke. But this maneuver can be done with bare hand in basket. The figure 1 shows some examples of maneuvers for live line maintenance.

### III. DEVELOPMENT OF VRTS

The goal was to develop a Virtual Reality Training System (VRTS) for training of operators in the maintenance of Live-lines in a distribution system. The system was designed in two phases: a non-immersive virtual reality system and an immersive virtual reality system. The following describes the stages of systems development, see figure 2.



**Figure 2. Stages for development of ALEN 3D system.**

The first stage is the definition. In this stage defines all the elements that make up the virtual environment. The information is collected through videos, manuals, plans, standards, procedures and also measuring equipment, materials and tools.

The second stage is the design. In this stage the information of the maneuvers is normalized. This stage is very important because all operators have to reach agreement on the steps of the maneuvers. Also the 3D models of the elements (equipment, materials and tools) are modeled to scale. The components involved in the virtual live-line work environment are modelled as 3D shapes to give them a more realistic appearance. Autodesk 3D Studio MAX (release 8) was used to model the objects. The system has a data base of 314 3D objects. The figure 3 shows the virtual environment.

The third stage is the construction of the virtual application: creating virtual scenes, animation and interactivity, audio and development of the interface. At this stage the ability to interact with the user and to generate sounds is developed. A script describes the interaction between user and virtual environment. In other way, describes the actions required by user to complete the maneuver. The interactivity of the virtual 3D scenarios was developed with the tool Cult3D

(release 2005). This tool defines valid clicks to run an animation, the type of navigation permitted (zoom, handling of objects), and selection of object from the menu of tools, materials, equipment. The VRTS interface was developed using ergonomic concepts.



**Figure 3. Virtual environment of the system.**

The interface is divided into three main areas: (1) information of the maneuver step to perform; (2) tools, materials and equipment menu; and (3) the virtual environment. This is the workspace where users interact with the system of training. 3D elements are mouse-sensitive objects that tell the user which areas are applicable to click on the current step. Valid clicks trigger 3D animations that show how to install the materials, how to operate the equipment and the location where the technicians should be placed.



**Figure 4. Virtual reality training systems interface.**

#### IV. RESULTS

After two years of work, the Alen3D system consists of 20 maneuvers for maintenance of high power line-live and a database of 314 interactive models. In total, there were approximately 1,600 minutes of animation, 800 objects were modeled (includes scenarios, avatars and structures) and

1,200 interactive scenes. Some of the results that we have identified are:

- The training process in high voltage live-line has been modernized and improved, because there are multimedia applications that capture attention and enhance the learning experience of the operators.
- The system has helped to reduce accidents during and after training.
- The system has contributed to the normalization and standardization of maintenance procedures for high power live-lines.
- The system has become a repository of knowledge and best practices and experiences.



**Figure 4. Training session using VRTS.**

#### V. CONCLUSION

In this paper we have presented the architecture of a training virtual reality system for power systems operators, the creation of the virtual work environment, and the collision detection among virtual objects.

The developed training system is based on non-immersive virtual reality. The training is focused on the maintenance of high power live-lines in a distribution system. Most work in power systems must be free of interruption, so it is carried out by live-line techniques. However, these techniques have increased the number of accidents by electric shock. Because most electric accidents are due to live-line work, it is important to train live-line operators. The proposed training system provides repeated and cost-effective training for a small space. It also guarantees safety during training operations.

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