AGITO: Virtual Reality Environment for Power Systems Substations Operators Training

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Abstract. This paper presents the architecture and development of a virtual reality environment for powers systems substations operators training. The proposal intents to reduce the training time for new operators and increase the effectiveness of the continuous training of operators. Using the simulation, the operator can interact with a virtual reality interface (immersive or non immersive) viewing the state of the power system captured through the supervisory system and acting through the virtual environment operating the substation, without exposing the system to dangerous situations, avoiding the occurrence of injuries of any kind. Also, the training sessions can be analyzed offline by an instructor.

Keywords: Virtual Reality Systems · Power Systems Training

1 Introduction

Power systems have a complex operation, needing qualified professional that are able to take complex decisions in order to maintain the compromise between safety and economy.

These systems must be working continuously. The monitoring and correct actions are fundamental for keeping it working. The capacity of identify the correct electric power system state depends on several factors, such as emergency and restoration procedures and continuous training.

Beyond power system complexity there are the inherent risks associated with the operation of power transmission and distribution systems. This training becomes a priority for a growing number of electricity companies. This continuous training is needed to keep the operator updated with the maneuvers,

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procedures and norms. This is fundamental to ensure the efficiency when performing procedures and also to maintain the operation process continuously.

Simulation-based training is an interesting option as they are safe for both personnel and equipment. Also, it offers to the trainee the opportunity to be exposed to several scenarios and critical conditions, even if them occur rarely or are hazardous to reproduce. The graphical environment may contribute considerably as they offer a better visualization of the electrical system state and guarantees a more effective training process.

Virtual Reality are one of the disruptive technologies. It may be seen as an interaction way between users and computers, where to the users is allowed to navigate and interact with a world represented graphically in 3D using multisensory devices [4].

Initially used for entertainment, this technology is largely perceived as an important tool in the process that involves content and procedures learning. This way, this technology emerges as a possibility for the construction of training environments in several areas, favoring the assimilation and experience of virtual situations comparable to real ones.

The application of virtual reality systems in training process has become an important application of this technology in industrial environment ([10], [14] and [6]).

Thus, we may verify that there is a need for simulation systems dedicated to the training of operators of power systems that are based on 3D graphical visualization and integrated to an electrical system simulation tool. The main goal is to allow training sessions creating mental images of the electrical system state and the spatial configuration of the electrical facilities.

This work aims to present the architecture and development of an virtual reality system that uses interactive 3D enviroments and gamification to provide a rich and objective interface for power systems operators training. It is done throught the integration to the Open System Supervision and Control (SAGE) [8] and simulated by a reference training implementation of EPRI/OTS, called SIMULOP [13] implemented in the context of the São Francisco Hydroelectric Company (CHESF) [2].

The remainder of this paper is organized in three sections. The Background section presents aspects of the SAGE system and its training using EPRI/OTS simulator. Then the system architecture AGITO presented as well as its main features. Lastly, held a discussion about the results previously found and on the following work that will be undertaken to improve the system.

2 Related Works

Several works have been proposed using virtual reality and simulation systems for the training of technical personnel in electrical systems companies.

The ESOPE-VR is a virtual reality environment representing an electrical substation with a two level interface representing the electrical panels (control room) and supervisory software [3]. It has an architecture based on the Expert

System Operations Planning Environment - ESOPE where the operators may interact with a line diagram representation of the substation system.

In [9] is presented a system for the training of operators focused on the simulation of faults to train the operators in diverse types of occurrences. The system is integrated with SAGE (Open System For Supervision and Control) and is composed of three modules to: edit scenarios, simulate the operation and analyze the performance. It does not offer a virtual environment.

A simulator developed for training electric systems operators is presented in [1]. The simulator allows training on the operation of substation panels as well as on supervisory systems. It presents the representation of a supervisory system and a tutor module that allows planning, implementing and evaluating of training programs. The simulator underwent a functional evaluation, with the participation of users, representing both the tutor and the operator under training.

In [15] is presented an application designed to train electrical sub-station operators using virtual reality. The application offer functionalities for visualization of the substation and navigation in the virtual environment interacting with the elements, with the complete functionality of the sub-station.

In [13] is presented the architecture and development experience of a training system, named SIMULOP, used in electrical companies in Brazil. The system consists of an integration of an Energy Management System named SAGE with Operator Training Simulator (OTS). The integration was done based on the Common Information Model (CIM) [5], and developed a training infrastructure. Also, the paper presents general aspects about the experience of implantation of this training system and its use for operators training.

Thus we may see that several research groups are looking for the proposal of virtual reality systems for electrical operators training, integrated to the companies architecture of supervisory and control system.

3 Background

This section presents the basic concepts that are involved in the description and comprehension of the proposed system. This consists of the supervisory system description and of its integrated training system, respectively SAGE and SIMULOP.

3.1 Open Supervisory and Control System (SAGE)

SAGE is an open system, in the sense of its architecture that is portable, expandable, modular and interconnected [8]. It implements the functionalities of energy management in control centers. Also, these functionalities may be configured for diverse applications from the automation of local facilities as substations or plants, till the application in complex operational centers based on heterogeneous network. Thus, SAGE system is presented as a unified solution for all supervision levels, reducing implantation costs.

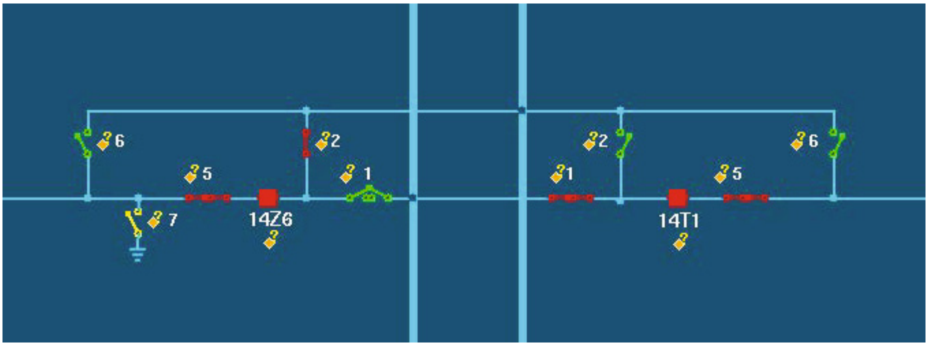

Fig. 1. Basic SLD diagram presented by SAGE interfaces

The substations could be operated by interfaces that represent the information in Single-line diagrams (SLD's) as exemplified in Figure 1. This kind of interface requires high level of application domain knowledge. That's one of the reasons why exhaustive training are conducted by the companies to enhance the operating capacity of correct acting when it is necessary.

3.2 Simulop

Simulop was developed to allow the use of the SAGE system for operators training [13]. It is a training simulator that allow the inclusion of scenarios in the context of CHESF, implemented as an integration of SAGE and EPRI-OTS (Operator Training Simulator) [11].

Simulop main objectives are: primary training of operators; adaptation to control room environment; complementary training, confronting the operator with extraordinary situations; qualification for operator upgrading and for procedures and network changes; and finally increasing the knowledge about the system.

The integration of SAGE and OTS was achieved through the use of a database compatible with the Common Information Model specification [5]. Simulop has been used successfully for operator training and certification in CHESF. But, it presents some limitations as the absence of trainee automatic evaluation, reinforcement learning and real contextualization of the scenario situations. These limitations may be overcome by using virtual reality techniques and information analysis, as a way to broaden the effectiveness of SAGE training scenarios.

4 Proposed System

As already stated, the main objective of the system proposed in this paper is the contribution to the enlargement of the effectiveness of a simulation based operators training system, through the use of virtual reality environments. This must be achieved, through the increment of the trainees capacity of synthesize and knowledge assimilation, elaborating associations between the real world and the simulated situations.

The system architecture was designed based on the following principles:

- Use of data collectors to acquire information from external systems, based on push events. This will allow that electrical system state modifications may be seen in the virtual reality interface, minimizing the communication overload of multiples clients to the central server, making the architecture scalable;
- Temporal labeling of all information collected, enabling its presentation in correct time;
- Development based on three layers - server, client and legacy systems, introducing facade elements for inter layers communication. This allows flexibility in the development making easier the change of layers and the reorganization or redefinition of roles in the system;
- Use of a 3D game engine to ease the activities of virtual world construction and interaction with its components;
- Extension by the use of plug-ins of the game engine to support the implementation of new functionalities.

Based on these requirements, we present in Figure 2 the architecture of the proposed system. The Figure 2 presents the role division as server modules that are in charge of the interoperability between the client modules (editor, viewer and supervisor) and the external systems SAGE/OTS.

The architecture is organized in three layers: SAGE/OTS, Interoperation and Client. SAGE/OTS layer represents the API and legacy systems that are integrated to the AGITO system. The Interoperation layer implements the middleware AgitoServer for the communication between SAGE/OTS and Client layer. Finally, the client layer has the software artifacts responsible for interaction through the AgitoViewer and AgitoSupervisor.

Layers Interoperation and Client are better described in the following sections

4.1 AgitoServer - Interoperation Layer

AgitoServer component is responsible for the communication to the SAGE/OTS offering a unique communication interface that enables an easy integration of services. The communication with the interface is done through a facade interface implemented on socket commands. To simplify, we grouped the information capture commands in four functionalities:

1. Equipment operation state, including measures and alarms
2. Record of equipment state change based on user actions
3. Notifications of equipment state change based on events triggered from the real time database. The viewer record these state changes, and stay in a loop. The feedback is done at every second, if any change is perceived. This is done to avoid an overhead of state requests by the viewer
4. OTS simulation scenario load and execution.

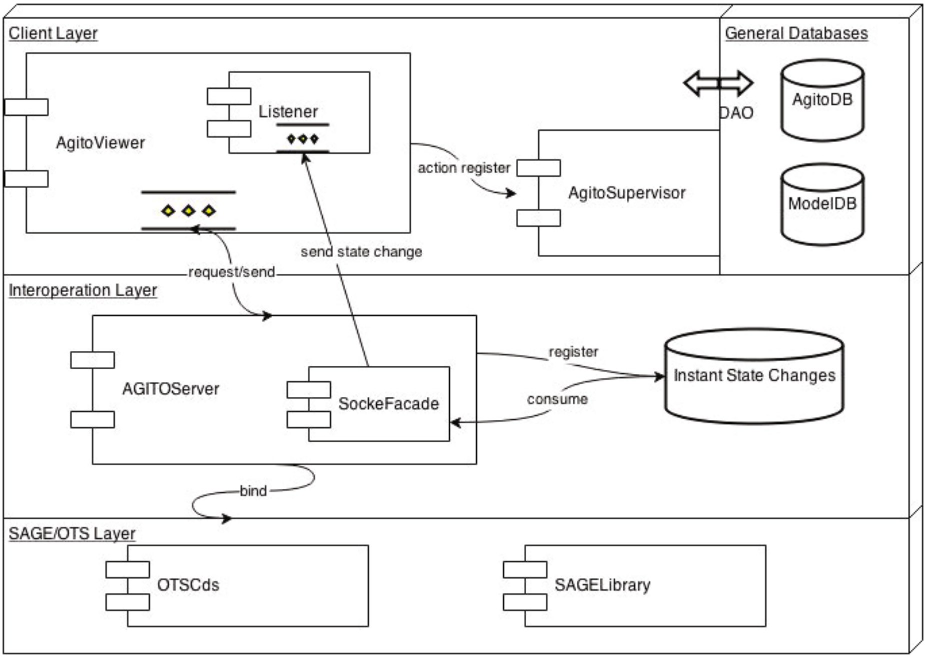

Fig. 2. Components view of Agito architecture

The communication is formatted through JSON to make easier the integration with other components of Agito: AgitoViewer and AgitoSupervisor.

4.2 AgitoViewer - Client Layer

It is implement using Unity game engine [16], being in charge of the visualization and interaction with electrical substations and all of their components. Figure 3 presents AgitoViewer initial interface when an specific substation is selected. The interface is organized in 6 functional regions, identified in Figure 3 by the letters A to F.

The region A represents the area where the equipment state is shown (Equipment State Control Panel). The equipment may be viewed individually in the pre-visualization panel (region B) where the selected one is shown. In C area is presented the minimap of the virtual world and the layers selection area (at the right). The layers are associated with predefined visualizations options, such as alarm or cables visualization. There is also a panel for equipment selection where is possible do change some settings of the equipment. In Figure 3, there are in this panel a voltage converter, with the option do adjust the TAP value. Also, there are two navigation control panels (regions E and F). One of them (region E) allow the control of zoom, pan and camera change. The channel of region F, permits the navigation through the power systems, changing the current substation to be visualized.

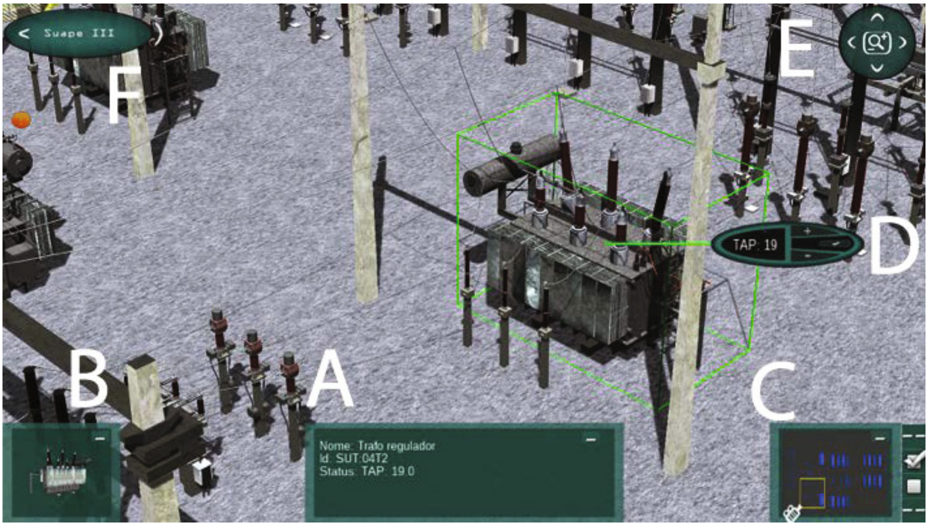

Fig. 3. AgitoViewer initial interface

All interface panels may be minimized to maximize the screen view area. Also, it is possible to visualize the scene in an immersive screen with passive stereo vision, as shown in Figure 4.

The viewer must be connected to the AgitoServer. This is necessary to acquire the equipment status and data making possible the visualization of them in the interface. Thus, there are in AgitoViewer, a listener module that is a multithreading system for information collection from AgitoServer. As new information is collected they are sent to the actually rendered scene.

To improve the responsive capacity of the system and to provide more interactivity, we implemented in separate threads the commands for equipment state change information acquisition, data request and users events collection.

Thus, we may see that AgitoViewer present as main functionalities a realistic visualization of an electrical substation (Figure 5a), with navigation through the virtual world (Figure 5b) and interaction possibilities. The user may set to maneuver equipments, visualizing the signalization of correct and wrong operations. Also it is possible to interact with simulation scenarios. During a trainning session the trainee actions are recorded and can be analyzed posteriorly by AgitoSupervisor. The alarm notifications are presented, with the representation of its location context and its cause (Figure 5c-d).

4.3 AgitoSupervisor

A simulation scenario, already defined in OTS, is a simulation of a real situation that is planned and defined by the supervisor, to create situations that can teach the trainees in the process of decision making. A scenario is compound by a sequence of actions that generates, in general, abnormal situations in the

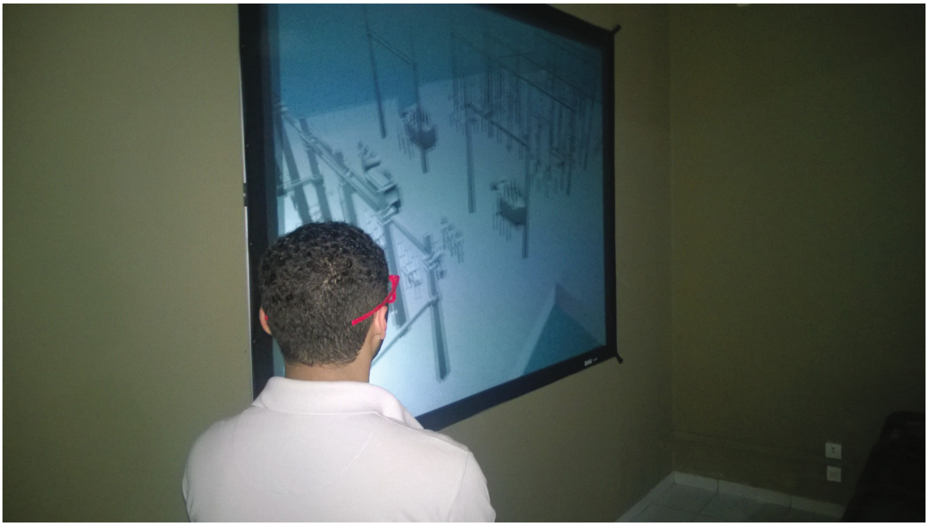

Fig. 4. View of a user visualizing the substation in a immersive room

system. Thus there is an expected response by the system operator to react to these situations.

As each situation can generate different operator response, and actions sequences, it was developed a module to enable the achievement of a qualitative evaluation of the trainee performance. This was done in the supervisor and evaluation module, named AgitoSupervisor.

This module aims the evaluation of user actions during a training scenario, assigning a score to him accordingly with his performance. Also, this module aims the support to the supervisor to perform a qualitative evaluation of the operator training session in a clear and short manner.

The implementation of AgitoSupervisor is based on gamification approach [12]. Each user action is recorded by the AgitoViewer module and is analyzed to see if it is appropriated for the situation. Depending on training configuration the system may give an immediate feedback indicating the wrong decision. Otherwise, the system can reward the user with score points that make possible a rank.

The simulation scenario previously created by the training supervisor could be started at any time in AgitoViewer and assisted by the automatic Supervisor at any time, making possible an offline training with automatic feedback. The proposal is that the training could be repeatedly perform for better understanding of simulated scenarios based on reinforcement learning [7].

Also the training supervisor could use more precise tools to analyze the learning and better optimize the scenarios directing efforts to situations that proven to wanting during the training.

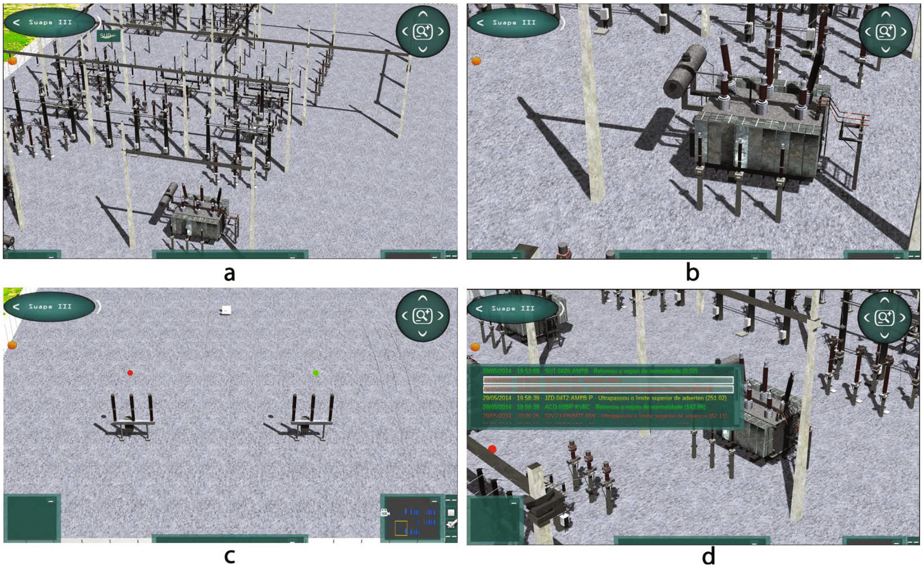

Fig. 5. Examples of AgitoViewer functionalities. (a) Initial screen with all panels minimized (b) Illumination and texture mapping aspects that improve the scene realism. (c) Visualization of alarms layers over the scene (d) Alarm menu with the alarm recognition option.

5 Discussion and Future Works

The use of interfaces with low usability and based on schematic diagrams such as SAGE, cause an cognition overhead in the learning stage. It is known that it is necessary rapid responses to a large number of situations. The process of reinforcement learning is applied to many companies as a way to turn simple those responses based on simulated experience.

The possibility of a virtual environment as a second view of the real world makes possible interactions with the environment, greater contact and visual appeal. Also we believe that the use of an environment similar to a game makes the training activity more pleasant. The AGITO work as second view, which does not replace the SAGE to operate the system during training sessions but increases the assimilation through visual representations of the real world.

Another improvement achieved by AGITO is the capacity of make a simulated scenario at any time. So, the operator could repeat any times he want the simulation and with this enhance his capacity of better handle real-time events when needed. The strategy of include the idea of games concepts also creates a healthy environment of competition to overcome the challenges that are characterized by the simulation scenarios. The expectation is that when implanted is to make training more efficient by conducting a more enjoyable activity.

As future work we intend to implement the visualization of internal electrical components allowing directly operating, simulating manual changes and allowing the inclusion of information to operator field. Another task is integrate the viewer with the rules of procedures adopted by CHESF to include a tutor mode during the execution of scenarios where the AGITO notice restlessness or doubt of the user by analyzing feelings. Some improvements in the runtime of the scenes should be added to decrease the charging time and allow more flexibility in exchange for substations and other operations. The proposal is that the scenes could be preloaded in the background even if they have not been accessed to allow quick access when requested.

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