RVCEMIG: Use of Virtual Reality in CEMIG's Operations Center

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ABSTRACT: *A Virtual Reality System provides intuitive tridimensional user interface, with distinct interaction when compared to traditional 2D widgets layout, allowing the user to manipulate data similar to real world. Such systems give the users physical and cognitive immersion, by granting a mental model compatible with field operation. This paper presents some development aspects and results of the GT 411 Research and Development project, involving CEMIG GT and the Federal University of Uberlândia. A VR environment is applied, in novel ways, in the training, operation and control of power systems. Such tool enhances Operations Center interaction capabilities by making use of multisensorial devices, with easy and natural manipulation and a high immersion level. Besides operating generation and transmission actives, the environment presents great potential for the training of operators and other professionals of support and maintenance.*

Keywords: Virtual Reality, Operator Training, Operations Center

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1. Introduction

Virtual Reality is defined as a high-end user-computer interface that involves real-time simulation and interactions through multiple sensorial channels or, alternatively, a simulation in which computer graphics is used to create a realistic new world [1]. Traditional applications include medicine, notably surgery and rehabilitation, education and entertainment, military-level simulations, manufacturing, robotics and information visualization.

The RVCEMIG project explores the concept of Virtual Reality in the operation of power systems, elucidating the potentials and impacts of this technology in operation and training. This project is now under way, entitled "Development of Virtual Environments for Operations Center of representative substations and power plants, associated with 3D projection technologies".

Virtual worlds based on VR technology allows engineers and operators to safely view and interact with process plants, without the risks present in the real environments. Among other key advantages, we can mention:

• The possibility of viewing, navigating and interacting with virtual structures similar to their real equivalents

• The ability of simulating operations and dangerous situation, without real damage to equipment, installations and personnel;

• VR technology provides better and more robust training [2];

• Allows the trainees to redo experiments outside the scope of a traditional class and lesson;

• Provides equal opportunities of communication for students of different cultures, due to a common representation

It is required that the VR system user interface provide interactive experimentation, as well as the possibility of dynamic changing the parameters that define the environment aspects [3]. For the human-machine interactions to be natural and intuitive, interface metaphors should be used appropriately. Such metaphors can be defined as mental models allowing the user the application of practical acquired knowledge in a virtual environment [4].

2. Development Process

The VR development requires the definition of a few concepts in the solution domain:

i. **Geometric Modelling:** Tridimensional models of real objects that composes the scenario;

ii. **Model Segmentation:** Definition of what and when will be rendered, avoiding memory excessive usage in the construction of the virtual environment

iii. **Interaction Metaphors:** Definition of specific hardware and software and the interaction with the environment, such that mental and physical immersion are accomplished.

iv. **Acoustics and Environment Modelling:** Definition of the transfer functions belonging to acoustics and other environmental factors

The process shown in Figure 1 has been created to address the specific problem of modelling virtual substations.

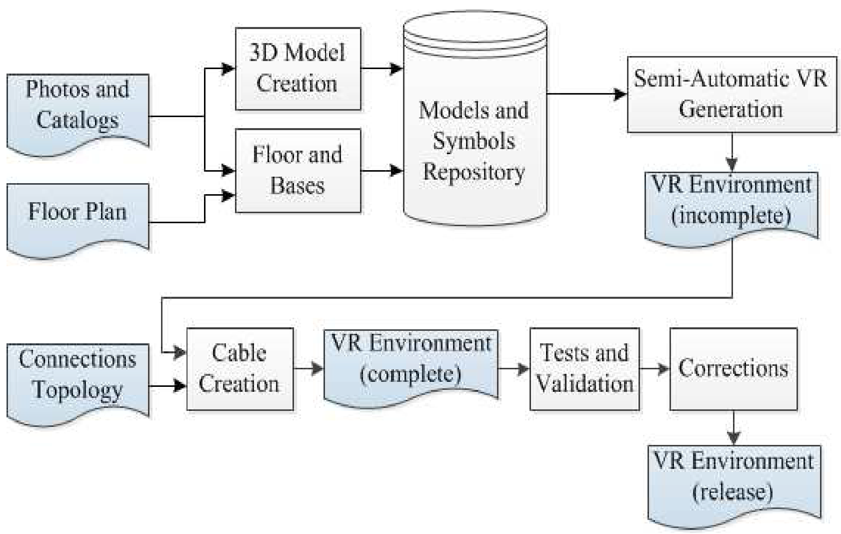

Figure 1. Substation Virtual Environment Development Process

Having photos and construction documents (CAD drawings, datasheets, catalogs) as inputs, the process starts with the geometric modelling of substation equipment. Each individual equipment 3D model is verified and validated, being stocked in a Model Repository, along with its photos and associated documents. A software package was developed to enable the easy and automatic placement of equipment on the virtual scenario, based on the positioning information contained in the substation floor plan. With such mechanism, a partial VR environment is generated, lacking cables and connections between distinct equipment.

The creation of the connections is done by another *ad hoc* tool, which is capable of drawing the cables using the topology as input. At the end of this process, the virtual environment is geometrically similar to the real substation (particular to each substation) and is then validated by field operators.

Once corrected, the virtual environment is submitted to the integration step, where each element of the scenario is associated to its unique identifier in SCADA (Supervisory Control and Data Acquisition) system. This provides the ability of presenting, in the VR environment, the state of each monitored device.

Finally, considering the authority directives, permissions flags and authentication mechanisms are set up.

3. System Features

The proposed system comprehends a set of realistic and integrated virtual environments, representing the substations of the CEMIG energy company and having interfaces for monitoring and control. A software layer was implemented inside the Unity 3D ™ game engine, allowing the reading and the real-time processing of equipment status. The communication is done by a Web Service provided by the company. By using this channel, the environment is periodically updated, accurately representing the state of the devices. It is equally possible to control and operate such devices.

The navigation can be realized in several ways, with custom angles and points of view, exploring and visualizing the condition of the different electrical components.

Due to the great similarity with the virtual and the real environments, the system is suitable for training activities.

Operators can explore and know in details the devices, besides simulating different operation actions without compromising their safety and system‘s performance.

The geometric modelling of individual equipment was done inside the Autodesk 3D Studio Max 2014 ™ environment. A set of conventions was established so that models are, at a certain level, standardized. These conventions concern dimensions and scale, pivot points for insertion, the amount of polygons etc. Figure 2 shows a Shunt Reactor virtual model.

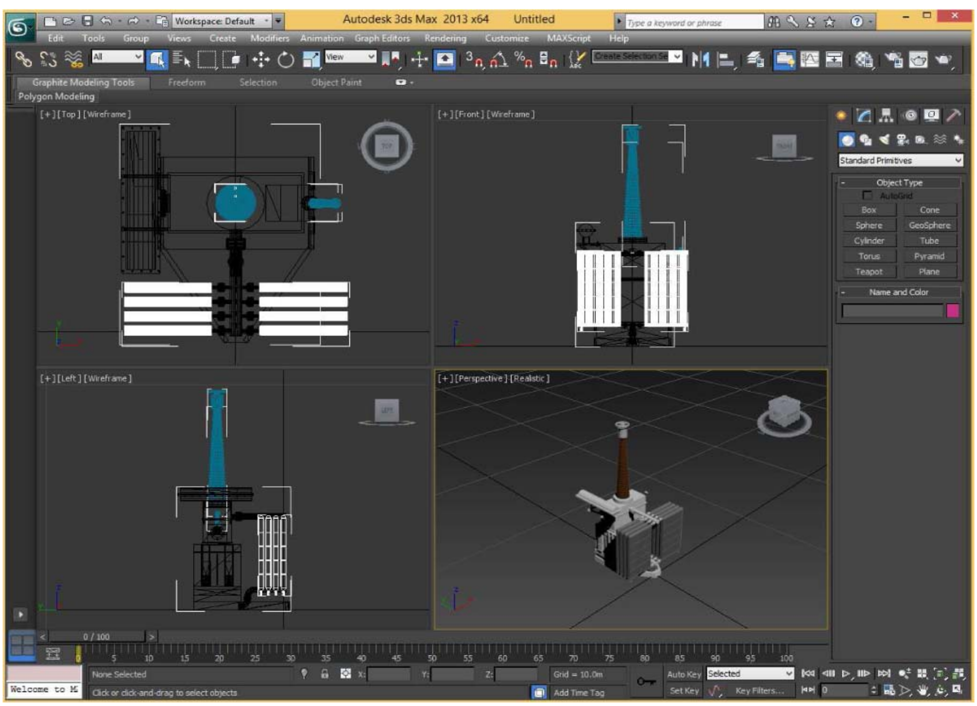

Figure 2. Virtual model of a Shunt Reactor

The environment is capable of bidirectional communication with the SCADA system, thus reading and modifying equipment state (Figure 3) [5].

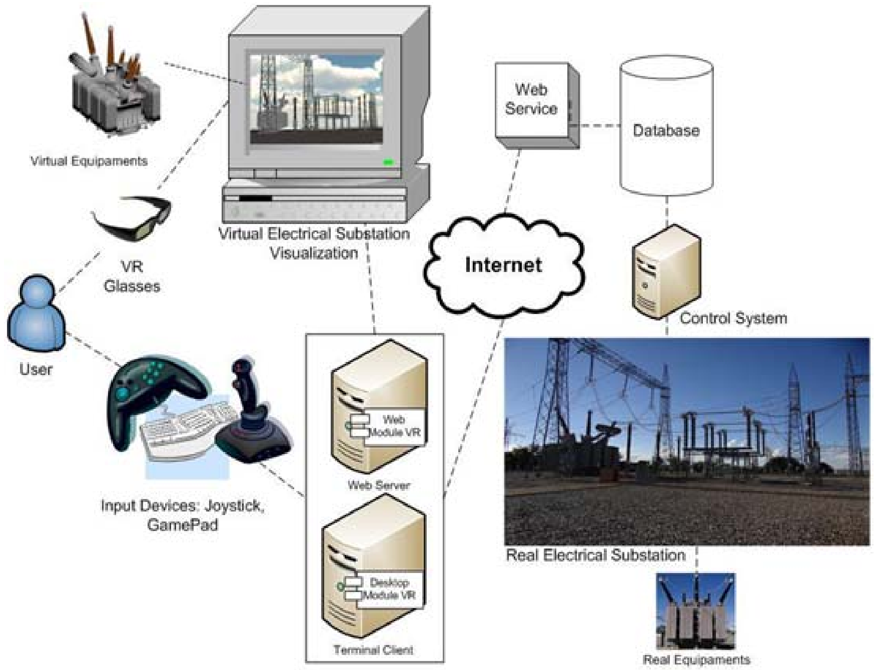

Figure 3. System Architecture

Traditional user interfaces, such as 2D widgets [6] may negatively affect the immersion in Virtual Reality systems [7]. The insertion of field data and widgets for control operations requires, as such, a specific study on usability, ergonomics and visual effects. The following directives were applied in this project:

- Every control interface should be integrated to the virtual environment, being arranged by their functional proximities;
- Every mechanisms should favor the principles of ease, speed and intuitiveness;
- Every widget on the interface should have a small amount of transparency, so that immersion is not severely compromised;
- Related actions and widgets should be grouped into layers, each of which might be enabled or disabled according to the user profile;
- Window should be easily moved in the screen or docked in a sidebar.

Figure 4 shows the selection of a transformer and the view of its associated real-time data.

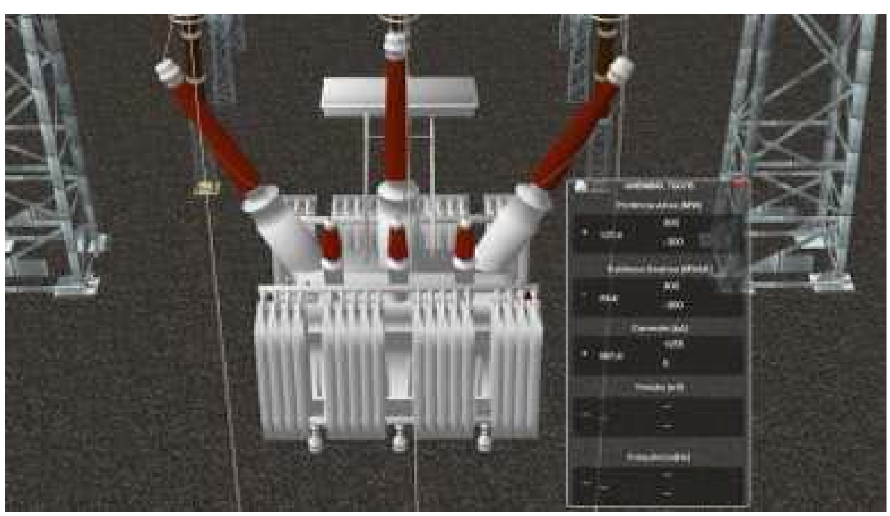

Figure 4. Transformer data visualization

The proposed user interface involves a sidebar with the auto-hide option enabled. When hidden, it occupies just a small portion of the total screen width, and does not present any quick access button, preventing accidental actions. In periods of inactivity, it occupies 15% of the total width and the actions are organized in menus and submenus. The widget sizes were established according to the Fitt's Law [8]. This Law restricts dimensions of buttons, menus, images and text fields according to the distance the pointing device must travel. It shows that, the bigger this distance, the less accurate the user will reach the target. The sidebar is shown in Figure 5.

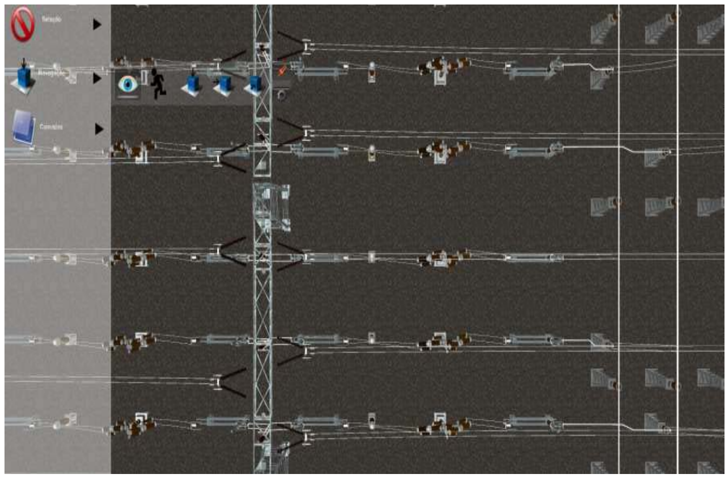

Figure 5. User Interface Sidebar

4. Results

During all the period of development and application of the methods presented in this paper, there was involvement of potential users (operators of CEMIG's Operations Center).

For the system requirements analysis, various methods were applied, such as: meetings, interviews, presentations of prototypes to the users, questionnaire forms [9]. The main results obtained so far were:

- High interest for the application;
- Good visualization of equipment state;
- Moderate difficulty in using the system (considering all forms of navigation);
- Easy learning;
- Efficiency on performing interaction commands;
- Preference for the traditional interface when it is necessary to perform the repetitive use of a given command;
- Pleasant appearance and aesthetics.

Concerning the difficulty in navigation, it is important to notice that most of the users consider themselves inexperienced on Virtual Reality environments.

5. Conclusions

The RVCEMIG Project seeks an innovation in the universe of human-machine interfaces applied to Electrical Power Systems. The developed prototypes have shown highly realistic environments, providing a real-time query system for equipment data and substation equipment geometry and layout, without the need of being physically present in the field.

Among the gains already observed, we can mention:

- Query and presentation system for different user profiles;
- Data visualization alternative approach, when compared to CAD 2D drawings;
- Electronic catalog of substation equipment

• Simulation of situations for maintenance and operational tasks planning;

5.1 Local Training

Most substations are remotely controlled, but need eventual operations *in loco*, particularly on the worst scenarios. They're assisted under fault conditions which demands inspections and repair actions. With time, many operators that knew a given substation in details were replaced by professionals that perform other activities, related to maintenance, and are occasionally assigned the operator role. These professionals must assist various substations.

It is believed that the VR interface will be of good help in this scenario, since it allows immediate access to any substation, without transportation costs and without the risks inherent to physical presence in the field. It might provide the maintenance of the familiarity with substation structure and layouts, as well as the common operation protocols, by training plans easily implemented and accessed.

5.2 Operator training in Operations Center

The use of this tool allows great progress on the operator training performed in the Operation Center, with geometry details of each substation, providing yet low costs and avoiding unnecessary travels. Besides, it allows for training and analysis of more than one substation, simultaneously.

5.3 Combined Remote and Local Training

The integration of the VR system with SCADA enables the combined training of field and remote teams.

The use of the training simulator with the VR environment allows a scenario where both local and remote actions are captured in the virtual world. The remote actions can be triggered by the traditional HMI or directly in the shared VR.

This kind of training can optimize the results and the trainees' performance, due to the tighter integration and standardization of the actions and requirements between both teams.

5.4 Use by Planning teams – Pre-operation

The pre-operation teams can benefit from the proposed system, since writing operation instructions and interacting with field teams can be accomplished more easily with a realistic and real-time representation of substations.

Personnel related to the intervention planning can easily visualize, along with the maintenance team, the regions demanding work, as well as the layout and configuration required to ensure safety on these operations.

5.5 Real-time Operation

The real-time operation team may also benefit from the system, with easier communication with the local team, due to the high similarity in both views. This can accelerate the diagnostics on faulty equipment. Inside the Operation Center, the VR would provide a richer and more intuitive interface. Also, the checking for safety conditions becomes easier, since the surrounding equipment and geometry are viewed. Control actions, performed on the real power system and from the virtual environment, is technically feasible and already available on the system, needing further validation and tests.

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