Simulator for Emergency Training on an Electrical Substation

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Abstract – **This article aims to present a prototype of a 3D electrical substation simulator with realistic models. The following software tools were used: to build 3D models of the equipment - 3DS Max - 3D Design Software; for moving and simulating 3D models - Unity Game Engine; for more special logical tasks - JavaScript. Situations are the most common events and related manipulations in the electrical substations.**

Keywords - **Simulation, Emergency Training, Electrical Substation.**

1. Introduction

Computer simulations are models of real or hypothetical situations or natural phenomena that allow users to explore the consequences of manipulating or modifying their parameters. Simulation differs from static visualization as it is dynamic. At the same time, simulation can be distinguished from dynamic visualization (e.g. animation) in that it allows participants to interact with it.

Simulations assist participants in observing and interacting with processes that may be invisible and therefore difficult to learn. These features make this activity valuable for understanding and hypothesizing various phenomena.

The simulations can be classified into four types, according to:

- the level of user control, the level of interactivity and participants' choice;
- the scope of the learning content (to what extent they are appropriate and related to the specific activity);
- how the information is presented - through text, graphics, symbols or abstract icons, or a combination of them;
- the essence of what is being modelled - these can be behaviour-based models, unexpected models, aggregate or summary models and composite models [7].

In order to increase security and improve electrical safety, it is necessary for the service personnel in the substations of the power supply systems to have not only knowledge of faultless performance of operational switching (OP). In order to create lasting habits for error-free performance of operational switches in substations by service personnel or trained specialists, it is appropriate to consolidate knowledge with visual training of specialized simulators.

The world's leading development is the Real Time Digital Simulator (RTDS), which is used by electricity suppliers to effectively study high-voltage networks. RTDS is a fully digital simulated real-time simulator. Today, several companies are developing RTDS for commercial purposes: RTDS of RTDS Technologies Inc. [9], HYPERSIM of Hydro-Quebec [12], eMEGAsim of OPAL-RT Technologies and others. In these software products through the GUI, specialized software and mathematical algorithms can be simulated any electrical network. When adding new equipment as well as removing old ones, the simulator configuration is refreshed in real time. This is used by designers and researchers of HV networks to simulate damage of all kinds (short circuits, element failure, high load loss, and power loss) by checking the operation of relays, protections, compensators, etc. Thus, RTDS are very convenient for testing physical devices and for visual training in real situations [2]. In our country only the high price is an obstacle for the wide application of these products in practice.

The present study with the help of computer 3D graphics recreates a 110 / 20 kV electrical substation. The selected substations are the most numerous and the emergency situations are the same. By imitating an almost real situation, the trainee will visually remember the sequence of actions, which will give him confidence in a real situation. A 3D virtual simulator has been created through virtual reality. It can be used both for training new staff and for refreshing the knowledge and periodic training of on-duty operators in substations. The simulated situations are basic in the performance of shifts in substations. The models used are as close as possible to the actual ones, which lead to familiarity with the equipment, and even those unfamiliar with the matter can get a real idea of the operation of the systems.

2. Research Methodology

The goal set in the research is achieved not by an individual, but by a pre-formed work team. During the development, various expert methods were applied - brainstorming, expert evaluations and other methods based on subjective evaluations.

The functional capabilities of the developed scenarios are compiled using:

- The professional intuition and qualification, as well as the life experience of the developers;
- Testing and inspecting such systems, interviewing workers and conducting surveys;
- Study of the safety of production systems in the same industry;
- Overview information on accidents, incidents and accidents, their causal relationships;
- Hazard analysis through checklists and other forms of research.

The methodology for simulation research created by us has the following positive sides:

- identifies and presents the main systemic hazards and related risks;
- provides logically substantiated data on the hazards that can be used in the design and operation of energy systems, as well as in investigating their safety;
- informs the management teams about the parameters of the hazards, which allows them to assess where and how to direct the available and necessary resources, in order for the risk to acquire acceptable values;
- it is carried out quickly and allows a relatively reliable analysis and assessment of the risk, provided that a sufficiently representative database of hazards is created.

Our experience shows that:

- The method does not have sufficient selective and resolving power with regard to the risk of combined hazards or those that arise in equipment with different principles of operation;
- the risk assessment is unreliable if inappropriate or insufficiently representative sites of impact or operational phases are analysed.

3. Software Tools

The following software products are used to develop the simulator:

- To build 3D models of the equipment, after studying the software products, the program 3ds Max design was chosen. It is a powerful system that provides solutions simultaneously in many sub-areas - modelling, lighting, rendering, animation and more. 3ds Max is used in many industries, including computer games, TV commercials and architectural modeling [1], [5], [8].
- The Unity game engine is selected for moving and simulating 3D models [4], [11]. The core of the program includes rendering of two-dimensional and three-dimensional graphics, physics, music, scriptwriting, animations, artificial intelligence, networks, streams and more. It is developed by Unity Technologies. The program has an integrated Monodevelop environment for writing programs, and the supported languages are: UnityScript (native language with ECMAScript - inspired syntax, which the software perceives as JavaScript), C # and Boo (which is syntax inspired by Python).
- JavaScript is used for more special logic tasks of the simulator, because it is one of the supported languages in Unity [3], [6], [10].

4. Program Implementation

In training mode there is a possibility for the simulator to suggest the next action, and in test mode this option is hidden.

The following types of activities are simulated:

- switching (work in Outdoor Distribution Systems (ODS));
- equipment management via control key;
- work with relay protections and automation;
- checking the serviceability;
- placing warning signs;
- use of personal protective equipment;
- telephone conversations with operationally senior staff.

In training mode, in the presence of a network, the instructor can observe the actions of the trainer from a distance, as well as intervene in the mode of operation of the equipment.

The development of the models went through three stages:

- Specification of dimensions and desired functionality
- Drawing a "raw" model
- Production and application of materials

3D models represent, in some cases schematically, and in others in more detail: Transformer 110/20 kV, Switch of type Oil Minimum Circuit Breakers (OMCB) 110 kV, Disconnector 110 kV with one and two earth blades, Voltage and current transformers, Control cabinets, Active resistance, Dashboard in the command hall, Portals in the ODS. Figure 1 depicts the finished model of OMCB circuit breaker and disconnector.
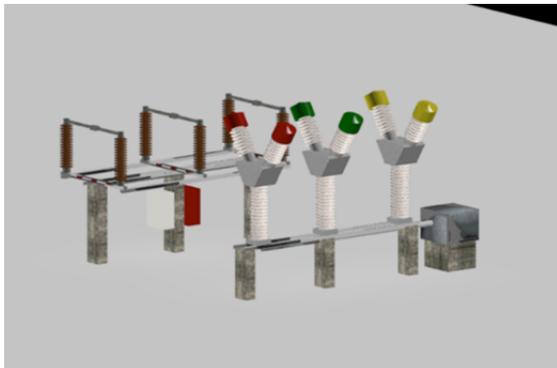

Figure 1. Model of OMCB circuit breaker and disconnector

5. Some Important Scripts

- For movement of the main object. The script added to the object via the FixedUpdate function simply recalculates the speed of the object, taking into account the input data from the mouse and keyboard.
- Point of view of the operator (camera). The vertical movement of the camera is performed by adding the transformRotate function with a position vector to the camera, and the "X" axis is set to monitor the "Y" movement of the mouse. This movement is not placed at the operator's site, but in the camera itself, because otherwise the operator's control becomes difficult for the trainee.
- Dispatcher. The Script Manager performs the most important work of the simulator. It starts the various emergencies and monitors the correct manipulations of the trainee. This is done in groups of nested blocks for each simulation separately. The checks are started with the start of the corresponding situation, checking the correct sequence and if it is executed, the ShowReport of the WindowsScripts class is changed, which

shows the manager report menu. If the sequence of any of the manipulations is wrong, the ShowHelp of WindowsScripts is changed and a panel with the correct manipulations is displayed. In addition to the functions serving the simulation situations, there is also the PhoneRinging function, which sets the beginning of situations "0" and "9". It simulates the ringing of the phone, and the trainee is expected to click on it to receive instructions.

- For 110 kV disconnector - Rotation right triple. The rotation of the disconnectors requires two separate scripts for the two triple disconnector blades, as at the same time one triple rotates clockwise and the other counterclockwise. At the same time, in order to observe the logical sequence of operations, objects have been added to monitor the position of the acknowledgment switch, the circuit breaker and the two stationary earthing switches.

In Figure 2 is shown an open 110 kV disconnector in simulator mode.

Figure 2. Open disconnector 110 kV

- Movement stationary ground blade 110 kV. To rotate the earthing blades (Figure 3) the same class Quaternion is used. This makes a realistic rotation of the blades in about 8 seconds. The variables used are for: zazemitelClosed - the position of the ground blade (used to block the disconnector); Kvitung - to create an object of type Kvitung to access the position of the acknowledgment key; Razedenitel - to access the position of the razedenitel; AudioSpeaker and ZazemitelAudio - to create realistic sound.
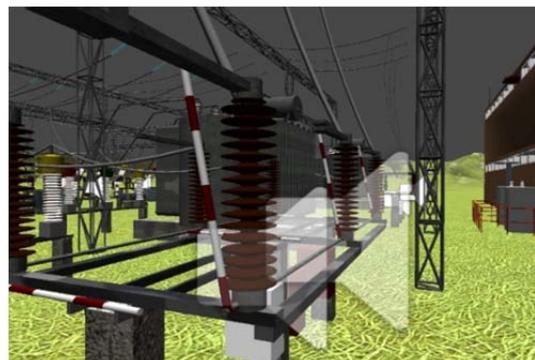

Figure 3. Closed stationary ground blade 110 kV

▪ Light indication in accordance with the position of the circuit breaker and the discrepancy switch. The light indication is performed by multiple light sources attached to the corresponding switch. There is a code attached to each of them (Figure 4). It creates a variable 'X' which is used to determine the period of illumination and extinguishing of the light source by changing linearly, and then normalizing (the change is reduced to the range from 0 to 1). The created objects are used for: 'KvitungLight' to access the variable 'FlashingKvitung'; 'Light12' control of the light source, which goes out when the program code is started.

```
var x: float;
var KvitungLight: GameObject;
var Light12: Light;
Light12.enabled=false;

function Update()
{
if(KvitungLight.GetComponent(KvitungBreaker)
.FlashingKvitung)
        {
        x=Time.time;
        x=x-Mathf.Floor(x);
        if(x<=0.5){
                Light12.enabled=true;
            }else{
                Light12.enabled=false;
                }
        }
}
```

Figure 4. Script for light indication

For each frame, the variable 'FlashingKvitung' is checked and if 'true', the naming of 'X' in the interval (0-1) starts for 2 seconds. This interval is divided into two equal parts, with the light source on and off on the first. Figure 5 shows a discrepancy switch in both states.

Figure 5. Discrepancy switch with light source switched off and on

▪ Zoom in on objects. One of the variables of the Camera class is used for a closer look at an object (protection, signal cassette, shield device, etc. fieldOfView determines the viewing angle of the camera. First, one should check if the zoom button is pressed is performed and if so, the viewing angle of the camera is changed depending on what the angle was before.

▪ Maximum overcurrent protection (MOCP). The activation of the protection is through the currents of the transformer supplied through the object CurrentObject, which is the ammeter (Figure 6). It is checked whether any of the phases has a current greater than 150 A and includes the corresponding blinker, as well as a switch-off signal via turnOn. ClickName clears the protection and SignalLight sends a signal to the valve from the Central Alarm.
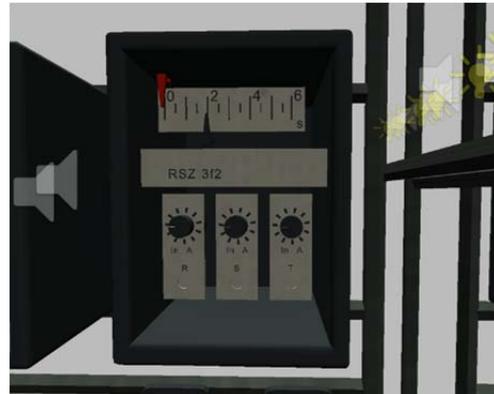

Figure 6. MOCP

6. Operation in Simulation Mode

After clicking the start button from the start menu, the substation scene is loaded. The duty officer is positioned in the control room (Figure 7).

Figure 7. Scene of control room

Until a situation is selected (buttons from zero to nine), the trainee is free to perform manipulations that do not contradict the locks. The locks act on the disconnectors and circuit breakers of the terminals, and the sequence of manipulations should be observed.

The sequence when excluding a terminal is:

1) Switch off the circuit breaker;
2) Switch off the linear disconnector;
3) Switch on the earthing blade.

When a terminal is turned on, the sequence is reversed. A manipulation will not be performed if the sequence is not followed. When a situation arises, the

trainee must perform a series of actions corresponding to the logic of the particular situation. If the sequence of actions does not correspond to the logically set ones, a help window is displayed with the precisely defined sequence of actions to be performed.

After the correct execution of the manipulations, a report to the dispatcher follows, which is done by clicking on the phone. This displays a window (Figure 8) with options for reporting the situation. If a report is correct, the window for a well done job is displayed. Otherwise, a window for incorrect report is displayed, during which the simulator expects correction of the report. After that the next event may occur.

Figure 8. Dispatch report board

7. Conclusion

A 3D simulator of an electrical substation with many realistic models is presented in this paper, which fully meets modern requirements. Models of the facilities have been successfully developed, as close as possible to the real ones. Scripts have been implemented, with the help by which the management of the models, the connections and the logic between them is achieved. The situations created are the most frequently occurring events and the related manipulations in the substations. Lighting and sound effects have been developed to create a greater sense of reality for the simulator user. This aims to create a dynamic environment in which the duty officer is placed when executing an order or in case of emergency. He is put in a stressful situation where he is required to make a series of certain decisions about what to do. The realism of the simulator allows easier orientation and memorization of the actions to be performed.

The main disadvantage of the proposed simulator is the lack of possibility to change the primary circuit. This limits its application a bit, but considering that 110 / 20kV substations are the most numerous and the emergency situations are the same, the simulator would be very useful.

Another disadvantage is that the simulator does not maintain the current position of switches and disconnectors when leaving the system. But this issue will be removed in future versions. Another important drawback is the need for relatively fast hardware. This is due to the fact that the models are made with high resolution and rendering requires a lot of graphics resources.

Acknowledgements

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