Development of a 3-D Immersion Type Training Simulator

Young-Beom Jung*, Chang-Hyun Park and Gil-Soo Jang†**

Abstract - In the current age of the information oriented society in which we live, many people use PCs and are dependant on the databases provided by the network server. However, online data can be missed during the occurrence of a blackout and furthermore, power failure can greatly effect Power Quality. This has resulted in the trend of using interruption-free live-line work when trouble occurs in a power system. However, 83% of the population receives an electric shock experience when a laborer is performing interruption-free live-line work. In the interruption-free method, education and training problems have been pinpointed. However, there are few instructors to implement the necessary training. Furthermore, the trainees undergo only a short training period of just 4 weeks. In this paper, to develop a method with no restrictions on time and place and to ensure a reduction in the misuse of materials, immersion type virtual reality (or environment) technology is used. The users of a 3D immersion type VR training system can interact with the system by performing the equivalent action in a safe environment. Thus, it can be valuable to apply this training system to such dangerous work as "Interruption-free live-line work exchanging COS (Cut-Out-Switch)". In this program, the user carries out work according to instructions displayed through the window and speaker and cannot perform other tasks until each part of the task is completed in the proper sequence. The workers using this system can utilize their hands and viewpoint movement since they are in a real environment but the trainee cannot use all parts and senses of a real body with the current VR technology.
Despite these weak points, when we consider the trends of improvement in electrical devices and communication technology, we can say that 3D graphic VR application has high potentiality.

Keywords: live-line work, power system simulation, sensor, training system, virtual reality

1. Introduction

Living in the information society as we do, computing equipments are widespread and popularized. The usage of such equipments is increasing without reprieve. A power failure can cause extensive damages to assets by effecting various electric in-home appliances and computing equipments. Information stored can become extinct and a task being performed can be ceased unexpectedly. To increase power supply reliability, power suppliers plan to reduce power failure. In 1995, operational blackouts decreased promptly from 80 minutes to 23 minutes per house due to an increase in the application of the interruption-free live-line method and temporary power transmission method in distribution work. Recently, 83% of electric shock accidents have happened during interruption-free live-line work. As well, the number of accidents of interruption-free live-line workers has been on the rise and causes of such accidents are inexperienced operation, mistakes, faults in device, and working environment.

The greatest problem in interruption-free live-line work is the training of interruption-free live-line workers. Some interruption-free live-line works are operated by unqualified workers and lack of time in a training course makes it impossible to train workers to be sufficiently skillful to work on the spot. The best way solve such problems is continuous on the spot training, but providing adequate adapting time for the trainee is difficult for the operating company. The safety of workers is still concerned.

Virtual reality is a technology employed to make users feel as if they are immersed in a particular setting by using computers to create a 'virtual world' that allows them to interact via human sensory systems to experience through various forms of feedback.

This paper uses 7 years (93.2~99.7) worth of data involving electric shock troubles in interruption-free live-line work, focusing on the interruption-free live-line work exchanging COS (Cut-Out-Switch), which forms 30% of the problems, and uses immersive virtual reality technology to develop a GUI (Graphic User Interface)[1] training system for interruption-free live-line trainees. The purpose of this paper is to develop a training system to reduce the existing riskiness and waste of expandable machinery and tools.

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2. Interruption-Free Live-Line Replacing COS

2.1 The Procedure

This is the standard work procedure performed in an interruption-free live-line COS replacing procedure.

Step 1: Insulation of neutral line and low-tension wire

(1) Put on rubber gloves and goggles

(2) Protect and insulate neutral line and low-tension wire

Step 2: Insulation of COS

(1) Insulate the COS sequentially

Step 3: Installation of a jumper cable

(1) Connect a temporary COS to the bifurcation ring compressing part

(2) Connect the 1st clamp of the jumper cable to the bottom of the temporary COS

(3) Connect the 2nd clamp of the jumper cable to the first bushing terminal of the transformer

(4) Hook a fuse holder to the temporary COS

(5) Install a fuse holder

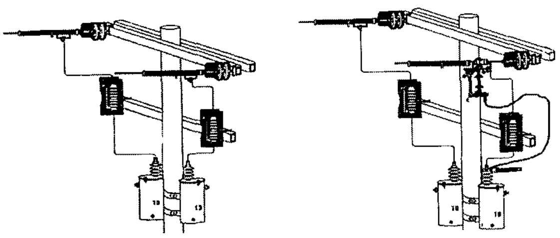

Fig. 1 Insulating COS & Power Line (left) and Installing COS & Jumper Cable (right)

Step 4: Replacement of COS

(1) Remove insulation cover from the COS of the transformer

(2) Open the COS fuse holder of the transformer

(3) Remove the 2nd lead wire of the COS from the transformer bushing

(4) Remove the 1st lead wire from the bifurcation ring

(5) Replace defected COS

(6) Connect the 2nd lead wire and connect the 1st lead wire to the bifurcation ring

(7) Install the transformer COS fuse holder with the COS operator bar

Step 5: Removal of a jumper cable

(1) Open temporary COS holder

(2) Remove the 2nd clamp of the jumper cable from the transformer bushing

(3) Remove the 1st clamp of the jumper cable connected to the temporary COS

(4) Remove the temporary COS

Step 6: Removal of insulators from neutral line and low tension wire

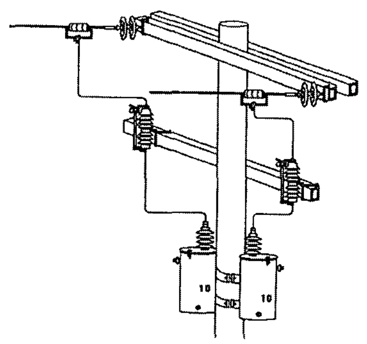

Fig. 2 Removing Jumper Cable and Insulating Facilities

2.2 Elements of the System

2.2.1 Visual Information

A user obtains 70% of external information through eyesight, thus three-dimensional eyesight and color sense are the most important factors in the virtual world.

Two-dimensional images are formed on the retina but sensed as three-dimensional images by the action of experimental and physiological principles. There are two methods in increasing the degree of immersion. The first is covering the user's environment with image space to magnify the display. The IMAX uses a screen of more than 10m in height and the OMNIMAX uses a dome shaped screen to give reality.

The second method used to provide a strong sense of immersion is HMD (Head Mount Display) [6]. The HMD is composed of a display and a location sensor to detect the location and direction of a head. The HMD traces the direction of a head based on the information from the space location sensor (Tracker) and supplies the images to the small display so that a user putting on a HMD can feel as if they are watching a vast image space.

In the interruption-free live-line replacing COS' operation, the worker getting on a cabinet of a live-line work vehicle uses a hand to control the movement of the cabinet and can move the sight at will understanding the environment. Thus using the HMD is the most suitable method to provide a high degree of immersion to the user.

2.2.2 Movement Information

In the interruption-free live-line replacing COS operation, movement information is composed of arms and hands. Most operations are performed by using a COS control bar with protective gloves.

The technology detecting the location in a three-dimensional space is required for the sensor system of the movement information. Detecting the movement means detecting the location of each part of a body along a time axis by means of axis, magnetic sensor, supersonic sensor and optical sensor. The magnetic sensor is used in this paper. The sensor can detect the location within a space without restricting the body. The magnetic field from a coil decreases with distance so detection of the distance becomes available.

In the case of hands, input devices such as data gloves are used. Inserting optical fiber into a part of the fingers, the data gloves detect the degree of finger bending movement. At the tip of the finger the optical fiber is formed into a U-shape. A light emitting diode is placed at one end of the fiber and a light receiving diode is placed at the other end. As the fiber is bended, the degree of transmittance is decreased and the degree of finger bending is detected.

3. The Development and the Process

To develop an educational training system employing immersion type virtual reality, a computer should create the training environment of an interruption-free live-line COS replacing work in the three-dimensional virtual space with scenes that give reality to the trainee through interactions.

An infinitive repeating loop is used for rendering composition of the scenes. The infinitive repeating loop is a typical method of window programming that repeats the process of receiving, processing, and waiting for data. Using this method, every data from each sensor is collected, processed and rendered as a new scene.

3.1 Simulation Tool (WorldToolKit)

WTK (World Tool Kit) [5] is a programming tool that enables a real time simulation, which is composed of about one thousand high level C functions. Each C function shows the ability corresponding to the general C code composed of thousands of lines.

The kernel of the WTK (World Tool Kit) is the simulation roof that updates objects and renders (5 to 30 frames per a sec) a new scene with data from each sensor. The main loop and the event dispatching mechanism of the WTK are similar to those of the typical window manager [4] but can be distinguished by focusing on the continuously changing viewpoint and objects in the space.

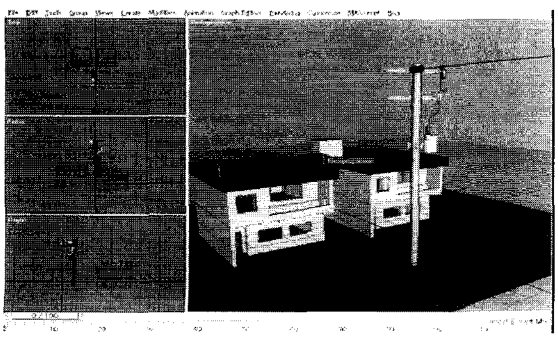

Fig. 3 Basic Elements Constructed in a 3D Space

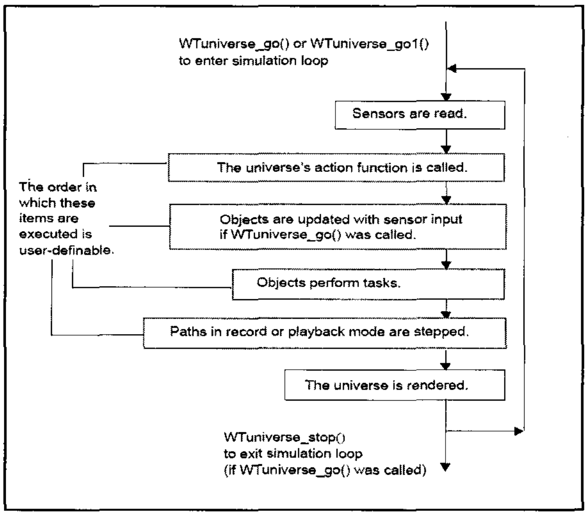

Fig. 4 Flow Chart of the Simulation [5]

The WTK uses the scene graph to organize a scene at each simulation loop. The scene graph is a layer structure used to organize a scene. Fig. 4 shows the shape of the scene graph and the sequence of scene building.

3.2 Layer Structure

When the trunk of the human body moves, every part of the body moves together. The WTK offers movable nodes to organize the movement more conveniently. Fig. 5 shows the structure of a movable node that is developed to express a movement and is composed of transform node, separation node and content node.

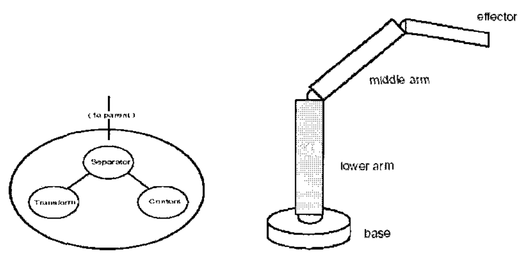

Fig. 5 Conception of the Movable Node and Hierarchical Structure [5]

A simple robot arm (Fig. 5) is composed of a base, a lower arm, a middle arm and an effector. The base is connected to the lower arm, the lower arm is connected to the middle arm and the middle arm is connected to the effector. If one part of the simple robot arm moves, its lower layers move together.

Similarly the arm and hand of the 'interruption-free live-line COS replacing operation' also form layers. If an upper part moves or rotates then its offspring nodes will move together and perform their own movements.

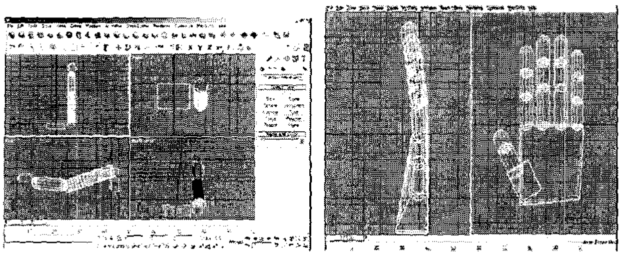

Fig. 6 Hierarchical Structure (from arms to finger)

3.3 Sensors

3.3.1 5DT Date Glove 16

The role of the data gloves is to detect the bending information of each knuckle along with the time axis and then to send the data to a computer.

To detect the information, the attached sensor (optical fiber) should be able to be bended according to the movement of the hand. The amount of light is read and transformed into a decimal numerical value and finally sent to the serial port of a computer through an interface cable. Fig. 7 shows the connection between a data glove and a computer.

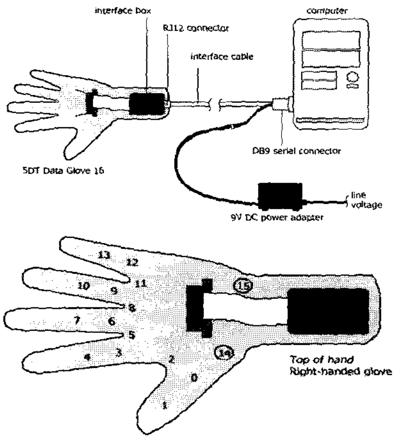

Fig. 7 The General Form of a Connection Between Glove and Computer [7]

The bending information in decimal integer from the data gloves is important data for a user's hand model in a three-dimensional space. The interface functions for each part of the glove of the manufacturing company should be available to obtain the information

3.3.2 Polhemus Fastrak

The Fastrak of Polhemus is a type of tracker detecting the location and direction information along a time axis. The Fastrak is composed of a body, a transmitter and a receiver. The transmitter generates the electro magnetic field and the receiver recognizes the location and the direction base on the transmitter. Fig. 9 marks the direction that the receiver recognizes and the size of the device. Along the marked axis, a programmer can attach the receiver to any part of the body and detect the degree of rotation.

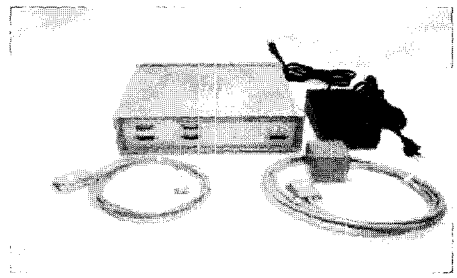

Fig. 8 The 'Fastrak' System [8]

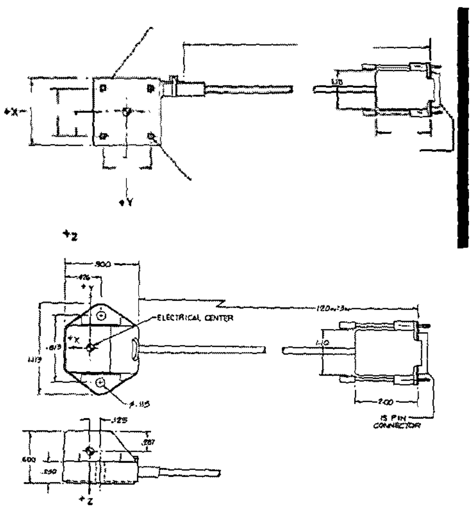

Fig. 9 Direction and Size of Receiver (upper) and Transmitter (down) [7]

3.4 Education System

Using a HMD, data gloves and the tracker SAVE (Safety Virtual Environment) model structure is chosen. A user puts on a HMD in Fig. 10. The tracker attached on the HMD detects the movement of the viewpoint of the user and sends the data to the graphic workstation. The HMD shows changed scenes of altered direction of the viewpoint. The scene of the trainee watching on the display varies as the trainee moves contact the head. Consequently the trainee feels as if he is in a three-dimensional virtual world.

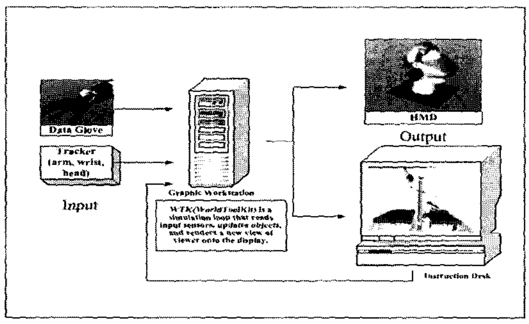

Fig. 10 Building Environments of Training System [1]

In the same manner, as the trainee moves or rotates his hands, the three-dimensional virtual hand moves and rotates in the same way.

4. Immersive Virtual Reality Training System

The kernel part to build up a user interface similar to the actual working environment for a live-line work trainee is to make the movements of hands and arms as authentic and close as possible to the real movement.

The immersive virtual reality education system deals with every movement, such as the wrist and fingers in operation. The shape of the arms are expressed as a wire frame shape to avoid discomfort when recognizing the work. Once the start button is pressed, the simulation begins with guidance with red texts on the screen and through a speaker.

4.1 Insulate low-tension wire

The trainee moves up to the low-tension wire to insulate with insulating cover.

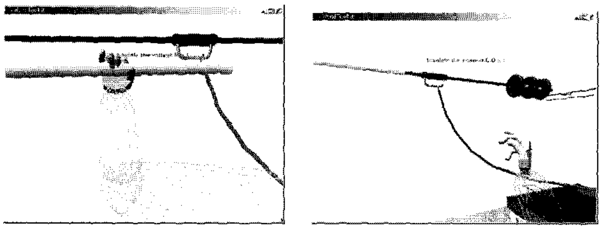

Fig. 11 Insulating Low Voltage Line

4.2 Insulate COS

If there are more than 2 COS installed, the trainee insulates COS one after another.

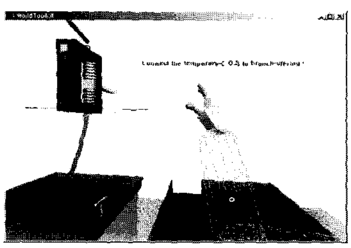

Fig. 12 Insulating COS

4.3 Connect temporary COS to the branch ring compression part

This step requires caution relating to the power line directly. The trainee assumes that rubber gloves are being worn.

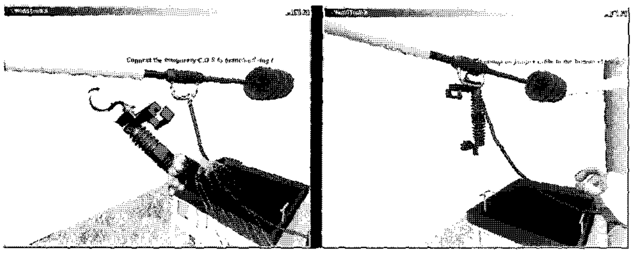

Fig. 13 Connecting Temporary COS

4.4 Connect the 1st clamp of the jumper cable to the bottom of the temporary COS

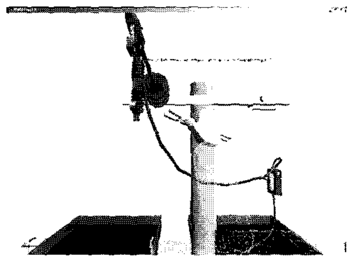

Fig. 14 Connecting the 1st Clamp to the Bottom of the Temporary COS

4.5 Connect the 2nd clamp of the jumper cable to the 1st bushing terminal

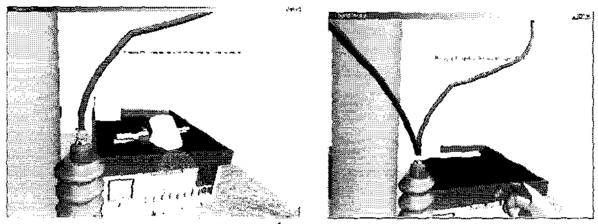

Fig. 15 Connecting the 2nd Clamp to the Bushing of the Transformer

4.6 Install temporary COS fuse holder

In interruption-free live-line work the power must be supplied while changing a COS. To supply power to the transformer in parallel install a fuse holder to the temporary COS.

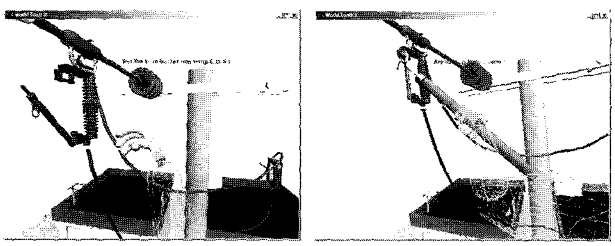

Fig. 16 Attaching a Fuse Holder to the Temporary COS and install it.

4.7 Remove the COS insulation transformer cover

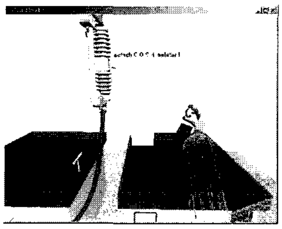

Fig. 17 Removing the COS Insulation Cover

4.8 Open COS fuse holder of transformer

Use a COS control bar to open the fuse holder.

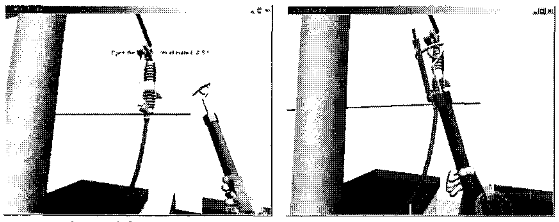

Fig. 18 Open the Fuse Holder in the COS

4.9 Remove the 1st and 2nd lead wires of the COS from the transformer bushing

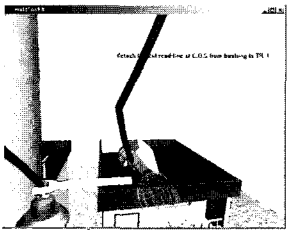

Fig. 19 Remove the 2nd Lead Wire between the Bushing and the COS

4.10 Changing a defected COS with a new COS

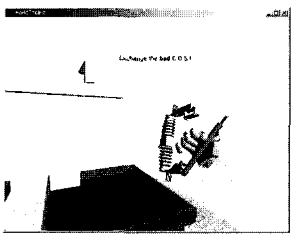

Fig. 20 Changing COS

4.11 Connect the 1st and 2nd lead wires to the COS

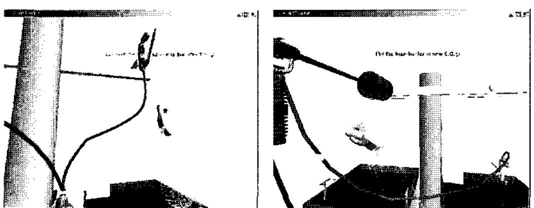

Fig. 21 Connect the 2nd and 1st Lead Wires to the COS

4.12 Install fuse holder into the new COS

Install fuse holder to supply power through the new COS of the transformer. Use the control bar to avoid arch.

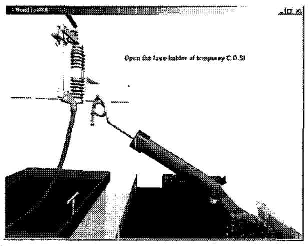

Fig. 22 Install Fuse Holder in a New COS

4.13 Open fuse holder in temporary COS

To remove the temporary COS open the fuse holder before removing the jumper cable.

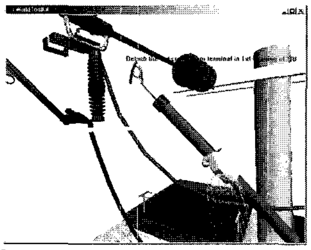

Fig. 23 Open Fuse Holder in Temporary COS

4.14 Remove the 2nd and 1st clamps of the jumper cable

Remove the 2nd and 1st clamps in order to connect the jumper cable to the bushing terminal of the transformer.

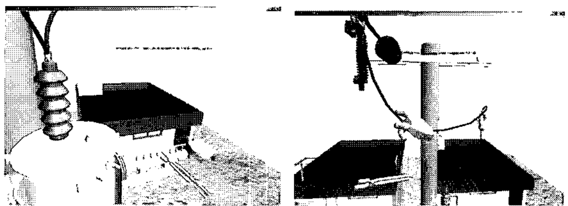

Fig. 24 Remove 2nd and 1st Clamps

4.15 Remove temporary COS and low-tension wire insulator

Now remove unnecessary temporary COS and low-tension wire insulator.

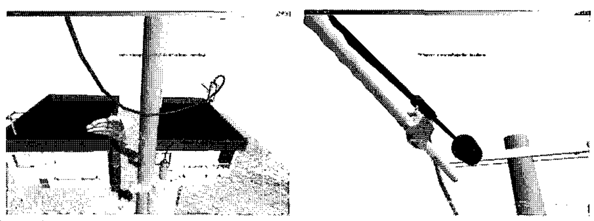

Fig. 25 Remove Temporary COS and Insulator of Low-tension Wire

4.16 End of task

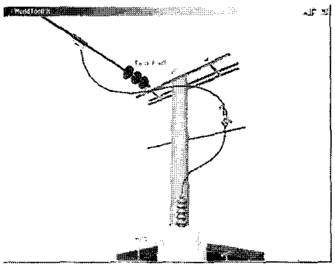

Fig. 26 End of Task

5. Conclusion

The method has been studied to solve the problems in education owing to the shortage of education period, lack of practical equipments and lack of practical trainers and to present new directions that allow trainees to be free from restrictions of time and of using semi-permanent equipments in the performance of interruption-free live-line COS replacing work.

In this paper, an immersive virtual world training system has been developed focusing on visual information to make a user feel as if they are actually in the virtual space and to increase adoptability at the job-site. The movement of a user in the real world is reflected in the three-dimensional space so that the user can participate in actions to a greater degree than just by watching and adapting the simulation to dangerous works, which is of great value.

Experiencing touch using VR technology costs an exorbitant amount. But, virtual reality is a developing technology based on electronic and communication technology. Considering the developing speed of modern hardware technology, the latent faculties of 3D virtual reality technology are infinitive. The purpose of the simulation is to make it as real as the real world. Developing the training system will involve building up the HCI (Human Computer Interface) and offering a basic solution for safe live-line work at point of time when reduction of electricity failure burdens the suppliers.

Acknowledgements

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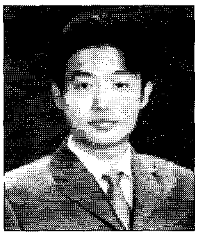

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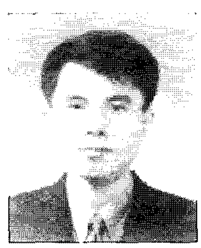

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