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Development of a 3-D Visualization Application for Management of Substation Equipment

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Abstract

This paper presents a new windows application based on 3-D graphics and Text-To-Speech (TTS) for effective management of substation equipment. When problems in a power system occur, inexperienced power system operators may have difficulty in understanding the situation as well as finding suitable countermeasures quickly. This paper addresses an effective scheme to visualizing power system equipment under normal and abnormal conditions using 3-D graphics and animations. In addition, the state variations and the order of maintenance priority of substation equipment are represented by TTS and intuitive methods. The proposed system can help power system operators to more quickly understand the state of power system equipment, and it can provide operators with the suitable countermeasures for minimizing damage caused by equipment problems.

Key Words : 3D Graphics, Equipment Management, Preventive Maintenance, Visualization, Windows Application

1. Introduction

Electric power systems have become vital elements of modern society, providing clean and convenient energy to power most of human facilities. When a small power failure occurs, the social and economic effects can be enormous [1]. Major system failures causing the collapse of a secure system are rarely the result of a single disturbance. Therefore, it is important to prevent potential trouble in advance, and if they do occur, to minimize the damage to the power system by the prompt action of the operators. Because the stable operation of power systems still depends on the operators' decisions, they must have a clear understanding of the current conditions in a power system. In addition, they must also have the ability to quickly analyze emergency situations and take the appropriate remedial actions promptly.

Several systems for operator's task such as fault diagnosis and maintenance have been developed [2-3]. The great parts of them are rule-based or skill-based methods from the standpoint of operator's tasks. Such systems are inadequate in some cases like emergency which needs prompt and accurate measures, since there are possibilities to make less reliable results due to troublesome

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procedures to ask and answer. Also, 2-D based HMI (Human Machine Interface) of SCADA (Supervisory Control & Data Acquisition System) in substation is inadequate for operators to have clear understanding of the system condition in case of emergency. That is because enormous chronological alarm messages generated by SCADA make unskilled operators embarrassed in an emergency. In the situation, trifling errors and inappropriate countermeasures by operators can cause a great damage to a power system. Hence, there is a strong need to develop a new HMI that enables operators to effectively understand current system conditions and help find suitable countermeasures even in an emergency.

In this paper, an effective windows application based on 3-D graphics and Text-To-Speech (TTS) for management of substation equipment is proposed. The developed application have the following functions: informing operators of the state variations of substation equipment by using 3-D visualization and TTS, informing the order of maintenance priority of the equipment, and reporting the standard countermeasures for equipment problems. In the remaining sections of this paper, the structure, modeling process and functions of the developed application are described.

2. Development Tools and Framework

2.1 3-D visualization

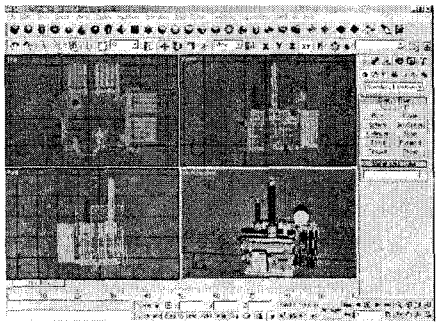
With the advances in computer technology, simple 2-D information can be now represented by 3-D technology. The 3-D technology has been used to create virtual model houses, 3-D virtual movies, flight simulators, etc. Interactive 3-D graphics and virtual reality(VR) [4-5] will become an important part of future user interfaces directed toward industry, science, business, and entertainment applications [6-8]. In the field of power engineering, several applications of interactive 3-D graphics were addressed. Interactive 3-D graphics technology has been applied for training operators in power systems [9-12]. In this paper, 3-D graphics were used to enhance a power system operator's perception and understanding of power system conditions.

2.2 3-D modeling and development tools

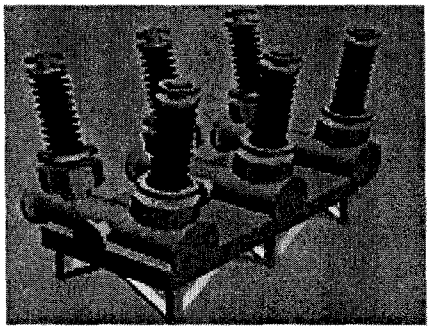
Currently, 2-D diagram and text based substation operator terminals do not provide the required information of the state of a power system promptly and efficiently. When problems occur in a substation, the successive warning signals on monitors and alarm sounds may confuse system operators. In this situation, it is difficult for inexperienced operators to find the appropriate means of settling the problems. The proposed application was aimed at assisting the operators to effectively understand the state of a power system and to precisely indicate the abnormal and breakdown parts using 3-D realistic equipment models. Every substation has several of its own transformers and circuit breakers, and the equipment is considered to be the main equipment in a substation. In addition, there are many difficulties in operating the equipment because of their complicated structure and large size. Therefore, transformer and circuit breaker are believed to be one of the main targets for the proposed application.

In this study, transformers and circuit breakers were modeled as a 3-D object in order to provide a more realistic expression to substation operators. The 3-D studio MAX [13] was used to develop

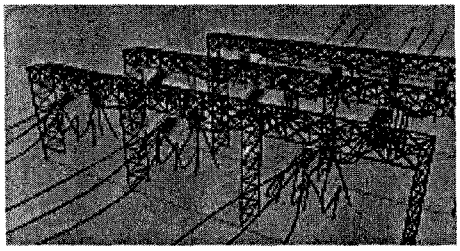
equipment models. Fig. 1 shows the 3-D modeling using the 3-D MAX.



(a) 3-D Modeling of Transformer



(b) 3-D Modeling of Circuit Breaker



(c) 3-D Modeling of Peripheral Equipment

Fig. 1. 3-D modeling using the 3-D MAX

A real-time 3-D graphic library such as the Open GL from Silicon Graphics and Direct X from Microsoft can be used to make interactive 3-D applications. Generally, Open GL is used in scientific application and Direct X is in entertainment like 3-D games. In this study, the 3-D graphic engine was made by using the WorldToolKit (WTK) [14], which is an Open GL based development library. The architecture of the WTK was designed to incorporate the power of scene hierarchies. The WTK allows a simulation to be constructed by assembling the geometry nodes into a hierarchical scene graph, which dictates how the simulation is rendered, and allows all the efficiencies of a state-preserving and stack-oriented rendering architecture [14]. The WTK is designed for use in real-time applications such as simulations, where the frame rates on the order of 5 to 30 frames per second are maintained [14]. Fig. 2 shows a simulation loop in the WTK.

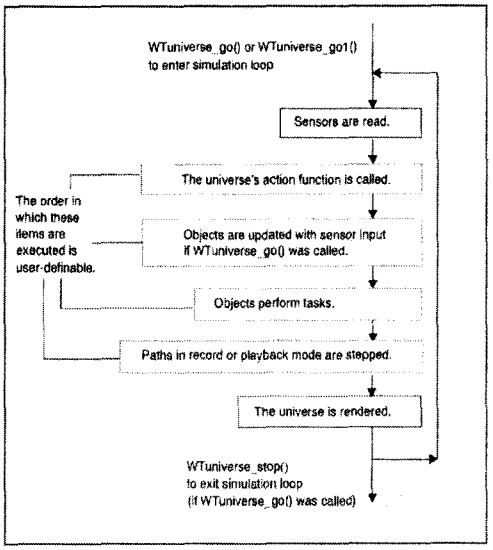


Fig. 2. WorldToolKit simulation loop [14]

In order to inform operators of the state variation of substation equipment by voice the TTS technology was used. The TTS is the leading technology that converts text data into human-like natural computerized voice by analyzing grammatical structure of the text and creating its proper speech intonation [15]. The

TTS converts various text data into voice and informs operator of the state of equipment to enhance the efficiency of equipment management. The VoiceTEXT [15], the TTS engine by Voiceware Co., Ltd. was used in the developed application.

2.3 Structure of the developed application

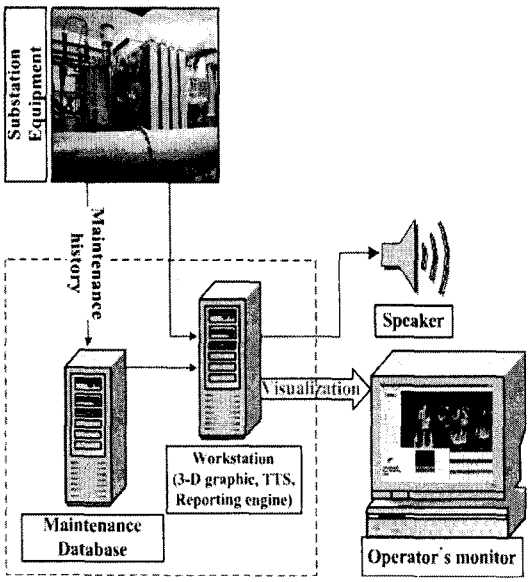


Fig. 3. Structure and process flow

The proposed application is composed of three modules. The first is visualization and TTS engine module. The 3-D graphic engine displays the state variations of substation equipment by realistic 3-D models on the operator's monitor and the TTS engine informs operator of the state through speakers. The second module is a searching and reporting countermeasures module. This module includes the standard countermeasures and troubleshooting procedures about various problems of substation equipment. The third module is the maintenance informing engine. This module stores the maintenance records of substation equipment and informs operators of the order of maintenance priority and appropriate maintenance schedule. The order of maintenance priority is calculated by evaluating equipment condition and importance in a power system. Fig. 3 shows the structure of the proposed application.

3. Management of Substation Equipment

3.1 3-D visualization of substation equipment

In order to provide convenient GUI, the mainframe of the developed application was made by using Windows Application Programming Interface(Win-API) and Microsoft Fundamental Classes (MFC) [16]. Fig. 4 shows the main window of the developed application. There are three kinds of windows in the screen: the 3-D model view, the 2-D graph view, the table view. The 3-D model view is identical with the actual substation and displayed as 3-D modeling objects so that the operator can intuitively recognize a current situation.

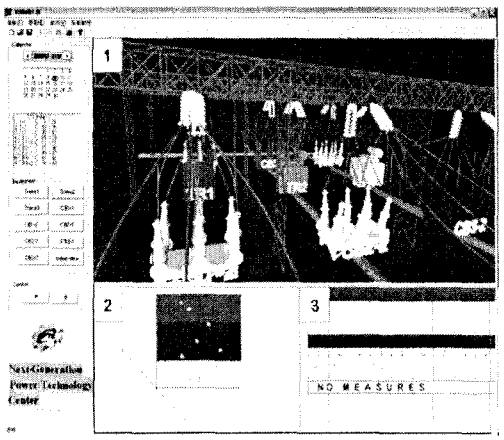
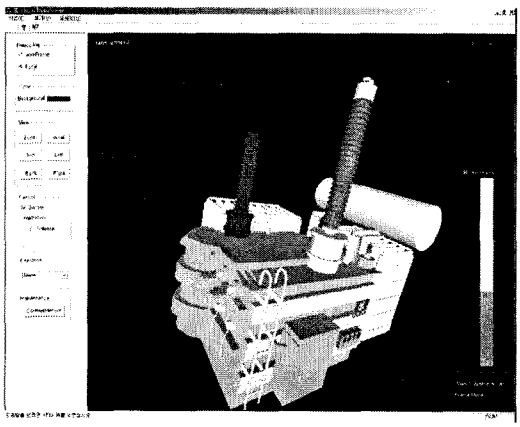


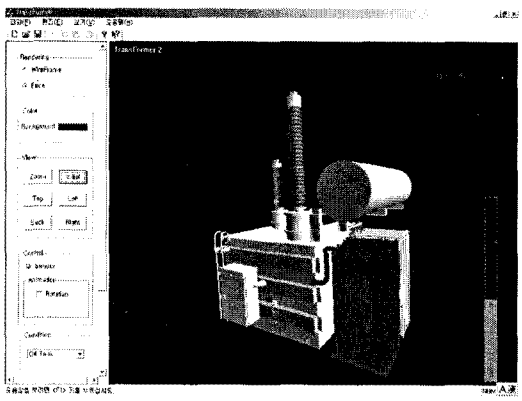
Fig. 4. Main window of the developed application[17]

When a problem occurs at a transformer, the detailed model of the transformer appears on the operator's screen as shown in Fig. 5 The operator can then easily find the location of the parts malfunctioning. The developed application represents the detailed transformer model swiftly with a changing color on the parts malfunctioning.

In addition, the developed application offers suitable countermeasures for equipment problems.



(a) Transformer with a problem in the bushing



(b) Transformer with a problem in the right cooling system

Fig. 5. Detailed model of transformer

For example, if a transformer becomes overloaded, it shows the requirement and pre-specified limits for the overload operating condition. The developed application then recommends the standard countermeasures for the overload condition. This realistic information is useful in making a decision for promptly recovering the system. Fig. 6 shows the standard countermeasures for increasing the insulating oil temperature at the overload condition. The suitable countermeasures for the overload operating condition are as follows:

(1) Installation of auxiliary cooling systems
(2) Frequent observation of the insulating oil temperature
(3) Observation of over-heating at terminal parts
(4) Report to the superior office when overload operation is impossible

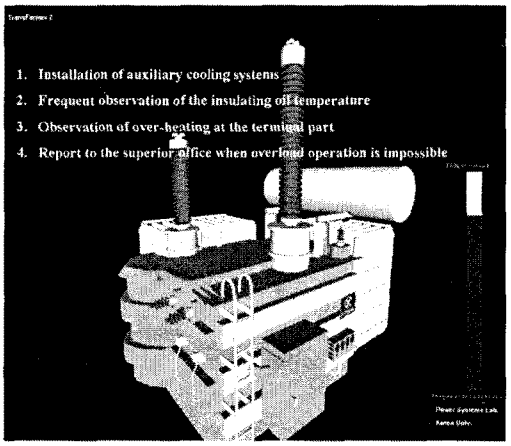
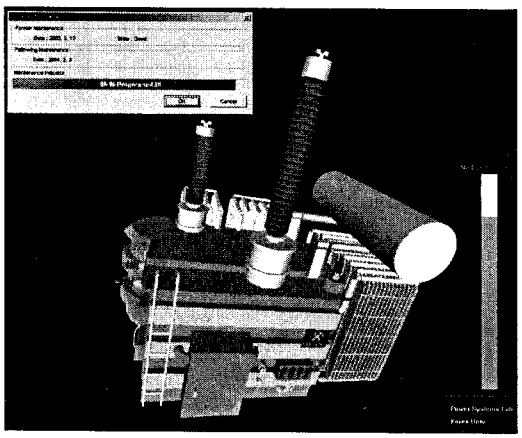


Fig. 6. Countermeasure recommendation at overload operating condition

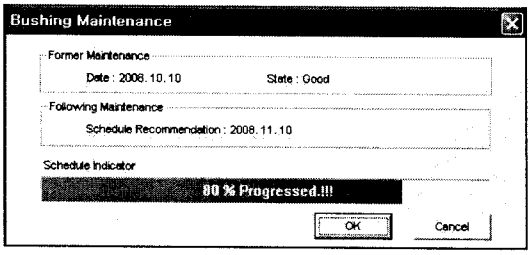
3.2 Preventive maintenance of substation equipment

The maintenance history and various test results of substation equipment are managed by a database system, which informs substation operators of the correct time and place for equipment maintenance. The operators can recognize the appropriate inspection schedule of equipment by clicking the mouse on a part of the 3-D equipment model, and they can see former

maintenance dates, the inspection results and the following inspection schedule by a visualized progressing bar. Fig. 7 shows an example of the dialog box of the former inspection results and the estimated following inspection schedule with a gradient progressing bar.



(a) Scene of informing the maintenance data



(b) Estimated following inspection schedule with a gradient progressing bar

Fig. 7. Information of the former inspection results and the estimated following inspection schedule

The developed application provides the order of maintenance priority of substation equipment. The detail method for estimating the maintenance priority was presented in [17]. The difference of colors is used for representing the state of maintenance. The state of each equipment is classified into 3 levels - Replacement, Maintenance and No measures. And they are corresponded with red, blue and gray color. Equipment that are included in Maintenance level is estimated the maintenance priority order. The depth of color is applied for indicating the priority order. The equipment which is expressed in the more deep blue color needs complementary measures prior to other equipment. Therefore operators intuitively recognize which equipment needs more fast maintenance. Fig. 8 shows the visualization of the order of maintenance priority of substation equipment.

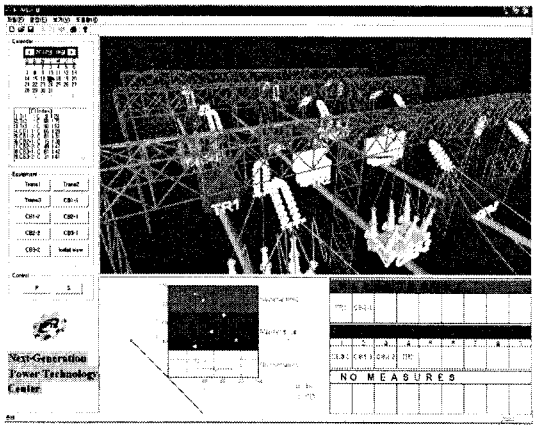


Fig. 8. Visualization of the order of maintenance priority

4. Conclusion

This paper presented a 3-D visualization application for the management of substation equipment. The developed application has functions such as informing operators of the state variations of substation equipment by using 3-D graphics and TTS, reporting standard counter-measures for equipment problems, and informing maintenance priority and schedule for preventive maintenance. The 3-D visualization and TTS engine enables substation operators to more promptly recognize the state variations of equipment and more efficiently decide counter-measures for equipment problems. In an emer-

gency situation, the developed application is helpful to prevent the enormous damage caused by substation equipment failures. Also, preventive maintenance function of the application contributes to the reliable substation operation. The author is going to enhance the interface in order to apply to many other types of equipment in a power system.

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Biography

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