**TELKOMNIKA**, Vol. 11, No. 5, May 2013, pp. 2663 ~ 2770
ISSN: 2302-4046



# A VR Based Anti-accident Training System for Airport's Power

**Gu GuoDong*, Mao XinLong, Tang ZhenMin**
School of Computer Sci. & Eng, Nanjing University of Sci. & Tech
School of Computer Sci. & Eng , Nanjing University of Sci. & Tech, Nanjing, Jiangsu, China.
+86-25-84315645
*Corresponding author, e-mail: machinelion@gmail.com

***Abstract***

*A virtual environment of airport's power supply is very useful for anti-accident training. In this paper, an effective method of anti-accident training for airport's power supply based on Delta3D VR engine was proposed. The architecture of airport's power supply training system was introduced. The electric closet's operating simulation was accomplished based on the device's operation logic. The model of fault and relay protection was designed according to electrical characteristics. A finite automaton model of diesel engine was presented based on operating conditions for virtual operation. Finally, a VR based airport's power supply system was built and verified in worker's training.*

***Keywords**: airport's power supply; anti-accident training; finite automaton; virtual environment*



## 1. Introduction

In the modern airport, with the rapid development of the power system, the equipments in the airport become more automated and the operation becomes more complex. So the workers need a higher skill level [1]. On the other hand, electric equipments and protective equipments' improvement reduced the probability of fault and abnormal operation greatly compared to the past. So it is difficult to improve the workers' capability of the incident handling in the daily operation. But the VR based anti-accident training system for airport's power supply can meet the requirements of training conveniently and safely.

A virtual environment of the airport's power supply was used in the anti-accident training. On one hand, the friendly interactive features can arouse the enthusiasm of the trainees [2]. With the system, trainees can improve their operating skills and accumulate experience. On the other hand, the virtual system can save the cost on training [3]. What's more, the system simulates the airport's power supply anti-accident training and ensures the training safety.

## 2. System Description

The system should accomplish the basic functions that the trainees patrol the airport's environment and operate the airport's power supply and distribution equipments [4]. The system should monitor if the system's topology changed and update the information of device status and the system's power flow. In the system, trainees can set the power supply equipments' operating conditions, such as normal, defect, and fault. And the trainees' operating records was stored from the beginning.

The system uses the C/S structure. Different machines communicate with each other with the Internet. The trainer machine manages all the trainee machines. Trainee machines operate independently of each other.

The system consists of the following five modules:

1. Electrical Simulation Module: For the calculating results of the airport's power flow. This module outputs the current, voltage, power, frequency and other information.

*Received January 18, 2013; Revised March 17, 2013; Accepted March 25, 2013*

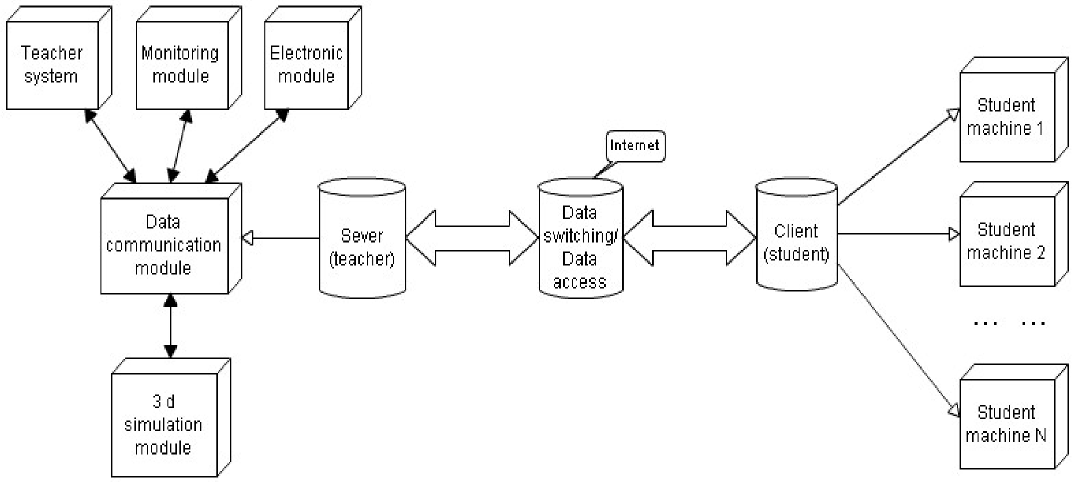



Figure 1. System Structure

2. Monitoring module: This module is used to acquire the telesignalling and teleindication signals of powered devices. All kinds of state quantity, analog quantity, and protective information are dealt with in this module. And the module receives trainees' remote control information.
3. Trainer system: In this module we initialize the simulation environment. Typical fault and defect are set and triggered. The module manages training process and evaluates the training results.
4. Data communication module: This module is used to accomplish the information exchange between different modules. It is in response to the topology changes in the system. And the status information of each device in the 3D scene is transferred to the electrical simulation module in this module. After the electric simulation module computing system's power flow, the monitoring module refreshes. And the system information in the three-dimensional scene would be update at the same time.
5. 3D simulation module: This module includes airport's power supply system, secondary equipments and airport environment model. The module responds to the power flow's change which the trainee triggered. Various types of faults are simulated in this module. What's more important is that the trainees can roam and interact in the virtual scene.

## 3. Airport's Power Supply Accident and Fault Description

The equipments of airport's power supply in many cases can't avoid the faults for the reason of designing flaws or operational errors [5]. So we analyze and classify the faults and exceptions that often appear in the airport. And then we simulate them in the virtual environment.

The faults of the airport's power supply in the system include electrical and physical faults. And they generally appear in the diesel power system, airport's marker lamps system and airport's runway light system.

Electrical faults include over-current, short circuit and ground faults. Physical faults include porcelain damage, wiring damage, and electric closet damage. Diesel power system includes battery's power supply abnormalities, fuel supply abnormalities, abnormal cooling system faults, and filtration system malfunction. Airport's marker lamps system includes power system faults, field voltage system faults, filament voltage system faults, and the filament high-voltage starter system malfunction. Airport's runway lighting system includes power system fault, dimmer system abnormalities, open circuit fault, the multipoint grounding fault, and the light damage.

The system sets the possible types of the faults to accomplish the effect of the anti-accident training, so the trainees can inspect and check troubles in the virtual environment.

## 4. Virtual Operation on Devices of Airport's Power Supply And Fault Simulation

Generally, the power supply system at the airport includes the center substation and the distribution Line. Airports use the dual power. The diesel generators are used as backup power. The main lines' electric closet at the airport substation are equipped with breaker and isolating switch, quick break protection, over current protection, and zero sequence protection.

### 4.1. Power Supply Equipments' Virtual Operation Based on Electrical Characteristics

During the airport's power supply anti-accident training, correct operation of the electric closet is the key content. We use the switching power supply (switch the supplying line from line 101 to line 102) as an example. The operating steps are as following:

Switch off the breaker on the outlet line side;

Switch off the 101 breakers and the isolating switch.

Switch on the 102 breakers and the isolating switch.

Switch on the outlet side breaker.

In the system, we can control different modules automatically on the control board. And we can operate the electrical equipments in the supply room. The instruments on the control board reflect the system power flow's information in time. See A in Figure 2.

Since different devices have different electrical characteristics [7], trainees may trigger different kinds of faults when they operate different electrical equipments. For some misuse, the system can accomplish the electrical equipment's protective locking function, according to the state of breaker, isolating switch and breaking lockout switch.

The protective latching logic uses the first-order logic. The followings describe the state of latching switch, breakers, and isolating switch:

Mk(i): Line k breaks the locking switch mode (1- overhaul; 2-break lock; 3-work).

Sk(m,n): Line k isolates switch m's state (m=0, 1; 0-up switch, 1-low switch; n=0, 1; 0-switch off, 1-switch on).

Bk(j): Breaker j's state in Line k (0- breaker off; 1- breakers on).

BreaLocking(p): Breaker p lock.

SwitLocking(q): Isolating switch q lock.

DoorLocking(r): Electric closet's door lock.

In the formula, k=1,2,3,⋯,N means the lines' number. There are N lines in total.

The followings are the distribution equipments' virtual operating rules:

a) $\forall$ i, j, k (Mk (i)=1) $\vee$ (Mk (i)=3) $\vee$ (Bk (j)=1) $\Rightarrow$ $\exists$ l1,l2 SwitLocking(l1) $\wedge$ SwitLocking(l2);

b) $\forall$ i,m,n (Mk(i)=1) $\vee$ (Mk(i)=2) $\vee$ (Sk(m=0,n=0)) $\vee$ (Sk(m=1,n=0)) $\Rightarrow$ $\exists$ p BreaLocking(p);

c) $\forall$ i (Mk(i)=2) $\vee$ (Mk(i)=3) $\Rightarrow$ $\exists$ r DoorLocking(r).

Based on the above rules, if and only if the breaking latching switch is at the "break lock" status, the breaker can operate the up and low isolating switches. Otherwise the switches refuse to move. And only if the breaking latching switch is at the "work" state, the up and low isolating switches can operate the breaker, otherwise the breaker refuse to move. Only if the breaking latching switch is set to "overhaul", we can open the electric closet's door and check the electrical equipments. See B and C in Figure 2 (Locking switch: left- Overhaul; right-breaking lock; middle-work).

A: control board


B: switch off wire 1# breaker C: switch on wire 2# breaker

Figure 2. Distribution equipments’ virtual operation

### 4.2. The Simulation of Relay Protection

In order to improve the trainees’ ability of dealing with the accident, the trainer machine can set single or multiple faults in the scene. Zero sequence which caused by a ground fault [8], over current protective operation caused by overload, and two relative short circuit and phase-to-phase short circuit protective actions are common faults in the airport power supply system. Based on the principles of each fault occurring, the system established the corresponding fault mode. Take setting the ground fault for example:

a). Create a model that trunk touch wires. Their position causes a ground fault;
b). The glazing plates on the control board alarm and the power flow change;
c). The electric closet’s ground protection leads relay power down;
d). After trainees finishing correcting the fault, the relay would recover.

The simulations of relay protection strengthen the trainees’ understanding of the processing flow. Repeated operation makes the trainees’ performance better.

### 4.3. Virtual Operation of the Diesel Engine

Airport’s power supply system needs diesel generator set as standby power [6]. We can open the system manually or through the way of the oil control cabinet. Mastering the startup process is another key content in the anti-accident training.

Based on the physical model of the diesel engine, the trainer machine can set the common faults of diesel engines, and simulate them, which include the battery’s abnormal voltage, the oil dipstick’s too low level, and insufficient coolant. The trainees should check the diesel engine before start it. If the fault exists, they must exclude it, or the diesel engine cannot be started. Abstract the diesel engine into a finite automaton. See it in Figure 3

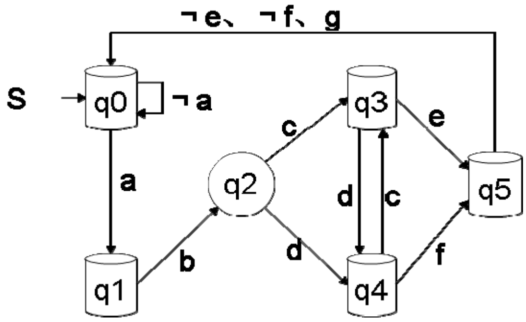



Figure 3. A finite automaton of the diesel engine

In the Figure 3,
*q0* is the initial state. Diesel engine has not been started;
*q1* is the “work” state for the diesel engine;
*q2* is the state that the screen initialize;
*q3* works for the starting automatically;
*q4* works for the starting manually;
*q5* is the state that the diesel engine starts;
*a* means that the preparatory work has been completed before the start;
$\neg$ *a* means that the preparatory work has not been completed before the start;
*b* is the power supply of the screen in the cabinet;
*c* means that the startup mode is on "automatic start" side;
*d* means that the startup mode is on "manual start" side;
*e* means the mains failure;
$\neg$ *e* means the mains recovery;
*f* means pressing the "start" button;
$\neg$ *f* means pressing the "Stop" button;
*g* means pressing the "emergency stop" button.

In the factor a in Figure3, checking the battery voltage is an important task before the diesel engine starts. It is important to create a realistic situation in the battery’s starting model for the simulation. In the case of precision permits, we simplify it to be the first order equivalent circuit. See it in Figure 4.

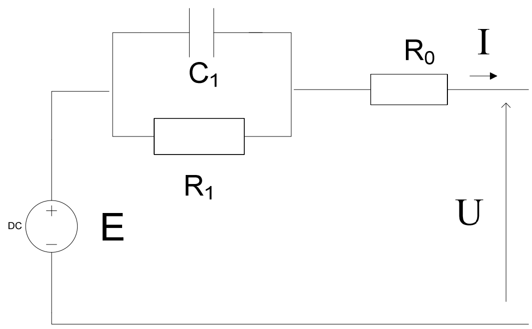



Figure 4. Battery’s equivalent circuit

In the figure 4:
$E$ -Open circuit voltage of the battery;

$R_0$ -Ohmic resistance and polarization resistance;

$R_1$ - The concentration polarization and electrochemical polarization resistance after the transition process;

$C_1$ -Differential capacitance inside the battery after the transition process;

And we also define the $R_{ex}$. It’s the resistance outside the battery.

Battery’s parameter is mainly affected by battery’s capacity, temperature and working current. We can get them by dealing with the experimental data in different conditions. The electric quantity of the battery changes with time. The relationship is as the followings:

$$u(t)=\begin{cases} \frac{ER_{ex}}{R_0+R_{ex}+R_1}\left(1+\frac{R_1}{R_0+R_{ex}}e^{\frac{-t}{r_p}}\right),\left(0\le t\le t_0, r_p=C_1\frac{R_1(R_0+R_{ex})}{R_0+R_{ex}+R_1}\right) \\ E\text{-}I_0R_0-U_{C10}e^{\frac{-t}{r'_p}},\left(t>t_0, r'_p=C_1\frac{R_1(R_0+R'_{ex})}{R_0+R'_{ex}+R_1}\right) \end{cases} \quad (1)$$

In the formula (1), t0 is the ending time of the battery discharging. I0 is the circuit current value at time t0. UC10 is the capacitor voltage value at time t0.

In the simulation experiment, we set 14 batteries and each has 2 volts. We get the process from discharging to the end. See it in Figure 5.

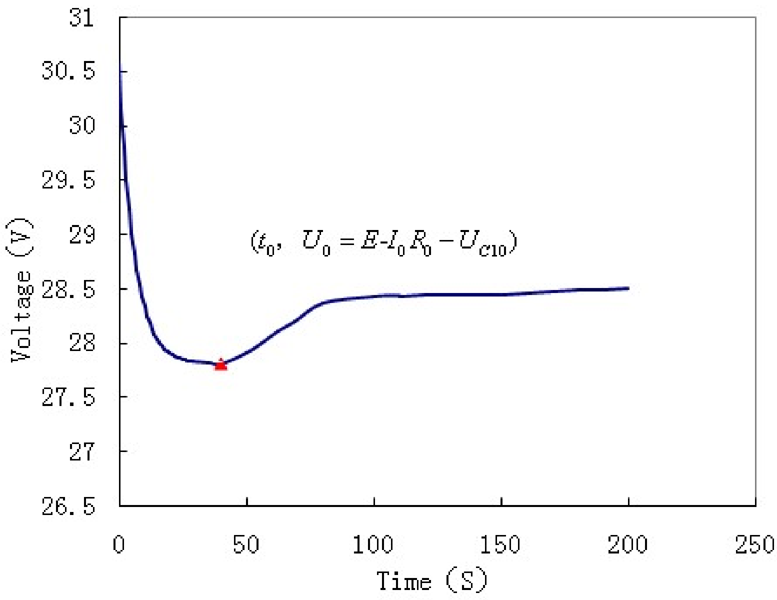



Figure 5. Battery's discharging process

Based on actual operating experience, when the voltage is lower than the minimum starting voltage of the diesel engine, diesel engine can't be started normally. The factors that affect the battery's voltage mainly include:

Insufficient battery capacity. Battery capacity affects various parameters of the battery, thereby affecting the output of the battery voltage. It is reflected in the model by using the voltage value at different initial time when the battery discharges.

Start the diesel engine too often. When we meet the fault of the engine at the first time, we should take a wait for 3 to 5 minutes. We must wait for the recovery of the battery's voltage and capacity. In the Figure 5, t > t0 is the time when voltage restores.

With the help of the oil dipstick, checking the oil level is another preparation for the diesel engine's starting. The oil consumption and the running time have the approximate linear relationships. And they satisfy the following relations (Hypothesis the oil density do not change during the operation):

$$V_F = V_E - \frac{P \cdot g_m}{\rho} \times 10^{-3} \cdot t \tag{2}$$

$$l_F = \frac{V_F}{V_E} \cdot l_E \tag{3}$$

In the formula:

$V_F$ -After operation, Lubricating oil volume, m3;

$V_E$ -Before operation, Lubricating oil volume, m3;

$P$ -The effective power of diesel engine, Kw;

$g_m$ -The Consumption rate of lubricating oil, g/Kw·h;

$\rho$ -The Density rate of lubricating oil, Kg/m3;

$t$ -Operating time, h;

$l_F$ -After operation, Lubricating oil dipstick level, cm;

$l_E$ -Before operation, Lubricating oil dipstick level, cm;

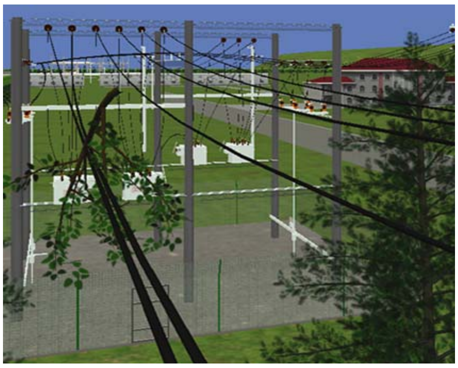
According to the formula (2) and formula (3), the lubricating oil is consumed when operating. Before starting up the engine, trainees should check the lubricating oil's level by dipstick and make sure it is in appropriate level. After starting up the engine, the lubricating oil is consumed and drop to the lowest level, which would have negative influence to the engine operation. We can watch the diesel engine operating parameters on the LED display [9], and make relevant records

### 4.4. Simulation Result

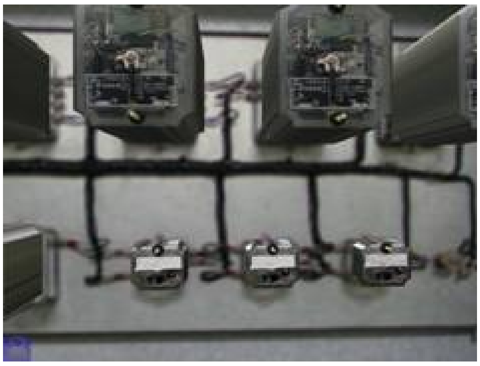
We simplified the relay's blocking protection logic to a first-order logical model. According to the training operation and the electrical characteristics of the airport's power supply, we simulated the power supply equipments' operating process.

We simulated the diesel engine's starting process by using physical models. We can watch the diesel engine's operating parameters on the display of the control cabinet, such as the oil pressure, water temperature, fuel level, and battery voltage. In order to enhance the trainees' experience, we set faults of the diesel engine and changed diesel engine's parameters by establishing the related physical model [10].

Based on the power supply equipments' physical and electrical characteristics, typical faults occurred and changed the power flow. Primary Equipments' state changing caused the power flow that is in the background changing. See it in Figure 6.

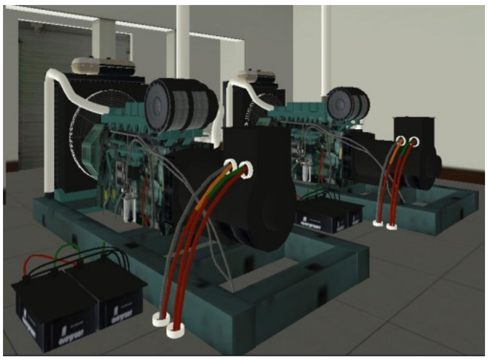


A. Phase faults situation



B. Relay device action

C. Control board light warning



D. Power engines

Figure 6. Typical scenes of virtual environment

## 5. Conclusion

We design a virtual environment of airport's power supply based on the Delta3D engine. The paper describes the structure of 3D virtual environment system and the process of creating the fundamental blocks. The virtual system can simulate airport's scene roaming and interactive operations, Airport's power supply equipments in the system can simulate normal, fault and other different working situations. This provided an effective method of airport's power supply anti-accident training.

Not long ago, the airport's power supply anti-accident training system has been successfully used in the airport's power supply training courses, and the system has a significant effect compared with the traditional way.

## References


[1] ZY Wang, F Chen. Airport Power Supply and AF-light System. *Civil Aviation*. 2001; 1: 9.

[2] ZY Zhou. *Research and implementation of virtual disassembly & assembly simulation training system*. Hunan: Hu Nan University Academic Publishers. 2010.

[3] Y Fei, Y GAO, T Zheng, LJ Huang. Design of a Real-time Interactive Visual System Platform Based on Scene. *Computer Simulation*. 2009; 2: 247.

[4] D Zhang. Research on Modeling and Optimization Technique of Distributed Driving Simulator. Wuhan: Wu Han University of Tec. Academic Publishers. 2008.

[5] W Ma. Research on the Performance Model and Estimated Strategy of SOC for Lead-Acid Battery of Electric Vehicles. Xi'an: Chang An University Academic Publishers. 2009.

[6] Standardization Administration of PR China. Measure method of lubricating oil consumption for diesel engines. GB14363-2009-T. 2009.

[7] Chenbin Tao. Switching power supply common mode EMI suppression technology research. *Tianjin: Journal of Tianjin University*. 2008.

[8] Zhang wei. The Electromagnetic Interference Model Analysis of the Power Switching Devices. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 11(1).

[9] Xin Xia, Shu-xin Zhu. A Survey on Weighted Network Measurement and Modeling. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 11(1).

[10] Zhenhui Wang, Qingfeng Zeng, Fengxia Guo, Dongpu Xu, Hao Wang. The electrostatic field networking in three isolated thunderstorms. *TELKOMNIKA Indonesian Journal of Electrical Engineering*. 11(1).