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The Experimental Study on the Ability to Manage Unexpected Events Using Micro-world Simulation

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Abstract: An experimental study has been performed to examine the inherent ability to manage unexpected events using micro-world simulation. Unexpected events are defined as the events occurring without prior training and description in the operation manual. The hypothesis that the subjects who can perform better in the preliminary stage of skill development tend to perform better in unexpected situations after acquiring the necessary skill has been tested on the basis of cognitive experiments. The dynamic micro-world simulation of a smart grid system (SGS), in which the subjects are instructed to maintain a grid voltage under dynamically changing conditions, has been utilized. In the preliminary experiment, the unexpected events and situations in SGS have been prepared and the level of task difficulty has been calibrated such that the task completion rate is equal to the intended rate. In the main experiment that followed the preliminary runs, 18 subjects participated in the experiments. The experimental results supported the raised hypothesis, which emphasizes the importance of an initial screening process for the human resources against the events beyond design expectation.

Keywords: Large-scale systems, Dynamic system, Cognitive science, Classification, Performance analysis

1. INTRODUCTION

The nuclear accident at the Fukushima Daiichi nuclear power station (1F) on March 11, 2011was caused by the Great East Japan Earthquake. Although the integrity of the power station had been maintained immediately after the earthquake owing to the designed safety features, the tsunami that followed the earthquake caused a station blackout, resulting in the lack of cooling. This was a type of an "unexpected event" for the operators who were at the site. Despite the enormous effort to recover the cooling function, the plants deteriorated and a large amount of radiation was released into the atmosphere, causing the evacuation of the people living near the site.

After this disaster, all nuclear power stations in Japan were shut down, and to realize a higher level of safety against the large-scale disaster, a new regulation standard for a nuclear power safety plan has been established. The new regulation requires nuclear power plants to manage a wider range of natural events such as a tornado, volcanic eruption, an earthquake, and a tsunami (Nuclear Regulation Authority, 2013). This new regulation focuses not only on the revision of the hardware safety system against these events but also refers to the required ability of the operator to handle a wider range of events. Although the plants approved by the new regulation will certainly become much safer against expected events, the possibility of events occurring beyond our expectation always remains. We believe that the role of the human operator with an adaptive capability is the key to dealing with such situations. (Takahashi, 2014)

The Boiling Water Reactor (BWR) training center (BTC), where most of the commercial nuclear power plant operators in Japan have been trained, has introduced a new severe accident training course to enhance the ability of the operators to deal with the extremely severe situations such as the Fukushima accident (BWR Operator Training Center Corporation, 2015). Although courses dealing with highly severe conditions may contribute to an enhanced ability to manage a wider range of situations that have not occurred yet, it is still unclear how to improve the essential ability to deal with unexpected situations. It is difficult or almost impossible to simulate an unpredictable situation . In other words, the definition of an "unexpected event" still remains unclear; it is also unclear how to define the ability to manage an unexpected event. Furthermore, how to simulate the unexpected events in training is a very difficult issue.

In our previous work, wherein unexpected events have been simulated in the micro-world simulation of a smart grid system, it has been implied that some subjects can deal with the unexpected situations better than the others (Horiuchi et al., 2014). However, evaluating the ability to manage the unpredictable situations is difficult. In the present study, we have mainly focused on three topics; (1) replication of unexpected situation by using simulator, (2) quantitative measure of the ability to manage unexpected situation, (3)

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examination of the reltionship of subjects' performance between expected and unexpected situation. Particularly for (3), the hypothesis that "performance during normal events is correlated with the performance in dealing with the unexpected events" has been experimentally examined. In the preliminary experiments, scenarios with different level of difficulty and unexpectedness have been experimentally evaluated and tuned to meet the requirements for the criterion. In the following experiments, the performance of the subjects for dealing with the scenarios has been evaluated focusing on the unexpectedness and the operation experiences.

2. METHOD

2.1 Micro-world Simulation

The smart grid simulator (SGS) has been adopted as the experimental test bed. SGS comprises four additional electrical sources, which can be utilized to stabilize the grid voltage that is determined on the basis of the balance between the incoming electrical energy from an upstream power station and the demand of the virtual city downstream (Nakanowatari et al., 2012). The demand varies daily, and the incoming energy also varies according to the pre-determined patterns. If the demands exceed the supplies, the grid voltage decreases and vice versa. The subjects have been instructed to the maintain grid voltage by controlling the four energy sources. Fig. 1 shows the main operation screen of the SGS. The screen shows the status of the four sources and the balance between demand and supply. The grid voltage is shown in the center, and the deviation from the desired value of 67.0 KV is indicated by the warning lights. The four sources have different characteristics depending on the nature of their power generation mechanism. The subjects should understand the characteristics and choose the proper energy sources according to the current situation. The characteristics and the instruction for each energy source, written in the operation manual are summarized below:

1. Wind Power (WP): The wind power generation system comprises two windmills with a capacity of 20 MW each. When the wind speed is between 3 m/s and 14 m/s, the output power is proportional to the wind speed, and when it exceeds 14 m, a fixed power of 20 MW is the output. The start-up time is 30 min (5 seconds in simulation time) and the start-up process cannot be aborted. The level of wind speed is indicated by the digit[m/s] and the warning alarm. Fig. 2 shows the sub-window for the WP system. Wind conditions have been determined in the experimental scenarios in advance. Because WP does not consume any fuel, it is economical and should thus be used frequently.

2. Solar Power (SP): The solar power generation system comprises two independent solar cell units with a capacity of 20 MW each. The output power is proportional to the intensity of sunshine. SP can be initiated immediately without delay and must be shutdown when the precipitation exceeds 50 mm/h. If SP has been already connected to the grid, it would shutdown automatically for safety reasons. SP should also be used as it is economical. Fig. 3 shows the sub-window for the SP system.

3. NAS battery (sodium-sulfur battery): The NAS battery system comprises two independent sodium–sulfur battery cell units (A-unit and B-unit) with each unit capable of charging and discharging 10 MW of electricity. It is assumed that the NAS battery should be charged during the night to prepare for the larger demands during the day. The operation of the NAS battery can be initiated immediately but the charging process requires some time. When one of the units is in operation (charge or discharge), the other unit cannot be operated; the system must be halted when switching to another NAS unit. Automatic shutdown would occur when a forbidden operation is performed. Fig. 4 shows the sub-window for the NAS system.

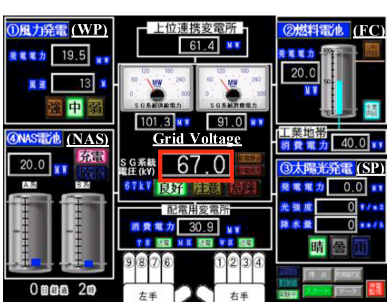

Fig. 1. Main screen of the Smart Grid Simulator.

Fig. 2. Sub window of WP.

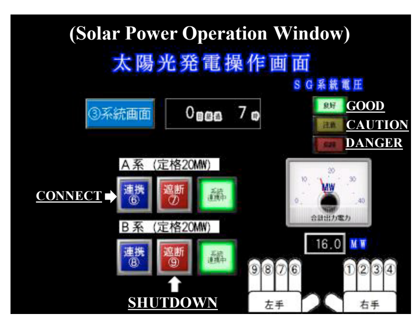

Fig. 3. Sub-window for the SP system.

Fig. 4. Sub-window for the NAS system.