New I&C Technologies for US-APWR –Verification of the Human System Interface and Emergency Gas Turbine Generator–

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We are planning to introduce not only the fully digitalized I&C system, including the screen based human system interface, but also the gas turbine generator, which will be the first application for PWR plants, as emergency power supply. This article describes the current status of the human system interface that is designed for the US-APWR and is under verification by the plant licensing operators of U.S. utilities. The article also describes the verification plan for the emergency gas turbine generator.

1. Introduction

Human factor engineering (HFE) program has been actively introduced to nuclear power plants with the goal of reducing human errors in the U.S. since the TMI (Three Mile Island) accident and is currently defined as one of the safety design review items. MHI, together with Japanese utilities that operate PWR plants, has developed the screen based human system interface (HSI) system in the main control room (MCR) since the latter half of 1980s. During the development, we have actively acquired the review trend in the U.S. regulations. The HSI system has already been installed in Tomari Nuclear Power Station Unit 3 of the Hokkaido Electric Power Co., Inc. as well as in other existing plants in Japan. Based on such experiences obtained from such installation, we are deploying the HFE program to apply this human system interface to the US-APWR.

The gas turbine generator (GTG) generally requires longer startup time of about several tens of seconds compared to the diesel generator but offers compact system configuration and needs fewer support systems (e.g., fueling and startup air systems), achieving higher system reliability and easy maintenance. Since the existing plants are required to be equipped with emergency electric power supply that can start up within 15 seconds in order to address events caused by the loss of offsite power accident, the rapid-start diesel generator has been installed in the emergency electric power supply. However, in the case of the US-APWR, the introduction of an advanced accumulator tank makes it possible to prolong this startup time of emergency electric power supply to 100 seconds. Therefore, we have determined to use the GTG as emergency electric power supply.

The US-APWR HFE program and the verification tests of the GTG are outlined below.

2. HFE program of the Human System Interface

2.1 Introduction

The Standard Review Plan (SRP) Chapter 18, which is a U.S. regulatory review standard, defines human factor engineering (HFE) and consists of 12 requirements (see **Table 1**). The goal of HFE is to reduce potential human errors over the whole plant process from the initial stage of

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design to the plant operation. These 12 requirements cover all human activities from those generated in the planning/analytical activity (e.g., HFE program development, operating experience review and plant functional requirement analysis, etc.,) to those in the design activity (e.g., human system interface (HSI) design, procedure development, and training program development) and in plant operation. Based on the experience of Japanese HSI system development, we have established a standard design process to meet the requirements of the U.S. review standards.

Table 1 Requirements for human factor engineering

Activity	Requirement	Activity	Requirement
Planning and analysis	1. Human factor engineering design (HFE) program management	Design	7. Human-system interface design
	2. Operating experience review		8. Procedure development
	3. Functional requirements analysis and function allocation		9. Training program development
	4. Task analysis	Verification	10. Human factor verification and validation (V&V)
	5. Staffing and qualification	Execution and operation	11 Design implementation
	6. Human reliability analysis		12 Human performance monitoring

2.2 Verification plan

After the new SRP was issued, there is no preceding applicant who was granted a license in the U.S. The Nuclear Regulatory Commission (NRC) is reviewing the adaptability of HFE to the regulatory review standard through discussions in industries task force. We repeatedly had discussions about the standard HFE process with the NRC to prepare the following program (see **Figure 1**) based on the NUREG-0711 guideline (Human Factors Engineering Program Review Model). In Phase 1, the current standard design for the human system interface was examined. In Phase 2, the standard design for the US-APWR's human system interface will be examined based on the results of the Phase 1 review. In Phase 3, the human system interface that incorporates site-specific plant conditions will be examined.

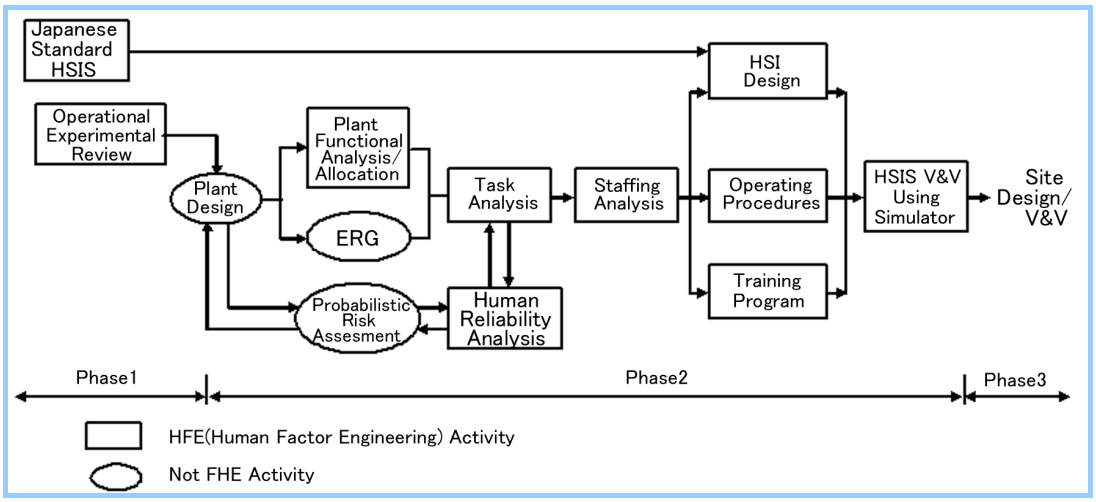

Figure 1 Human factor engineering (HFE) verification plan

2.3 Current situation of HFE licensing activities

We prepared a topical report and a standard design control document (DCD) relating to human system interface specifications based on the NUREG-0711 and submitted them to the NRC for review. In addition, we summarized the operating experience review, plant functional requirements analysis and function allocation, task analysis, and human reliability analysis, all of which are HFE requirements, in the form of technical reports and submitted these reports to the NRC.

To verify the adaptability of the current human system interface to the US-APWR, we examined the HSI design, one of the final evaluation indices, by acquiring operating procedures and operating experience reviews as information input to the plant design. To this end, we installed the human system interface verification facility (see **Figure 2**) in MELCO affiliate (MEPPI) located in Pittsburgh and requested the current U.S. licensing operators to verify the HSI system as

Phase 1 from July 2008. We, together with U.S. HFE experts, experienced licensing operators and U.S. utilities representative, evaluated the improvements to the operation console screen, functions, and layout design of the HSI system, all of which were obtained from the Phase 1 verification. We summarized the results of these verification activities in the form of technical reports and issued the reports to the NRC in December 2008 and June 2009, respectively. In the future, we will examine the standard design for the US-APWR's human system interface (Phase 2) with other remaining HFE program and the site-specific design for the HSI system (Phase 3).

Figure 2 Human system interface verification facility

3. Verification of the emergency gas turbine generator

3.1 Features of the gas turbine generator

The gas turbine generator is characterized by prolonged startup time compared to the diesel generator but operating and control methodologies are basically the same as those used for the diesel generator. Similar to the diesel generator, the gas turbine generator can address the continuous application of large loads required from the viewpoint of plant safety design.

The engine of the gas turbine generator features a reduced number of components compared to the diesel generator, application of a simple air-cooled system (the diesel generator uses a water-cooled system), and simplified support systems. Therefore, it substantially improves the potential reliability of the emergency electric power supply. Since the engine is about 1/7 the size of the diesel engine, cooled by air, and equipped with simplified support systems (e.g., fueling and startup air systems), the complete gas turbine generator offers a very compact emergency system compared to the diesel generator-based system. For this reason, the volume of space necessary for the emergency electric power supply equipped with the gas turbine generator can be considerably reduced compared to the emergency electric power supply equipped with the diesel generator (see **Figure 3**).

While the diesel generator generally needs to be serviced for about 2 weeks every year, the gas turbine generator can be maintained in a very easy way. Also, the emergency electric power supply with the gas turbine generator is so simplified that, when compared to conventional equipment with the diesel generator, it is expected to drastically cut back both maintenance workload and time period associated with maintenance activities (by about 90%).

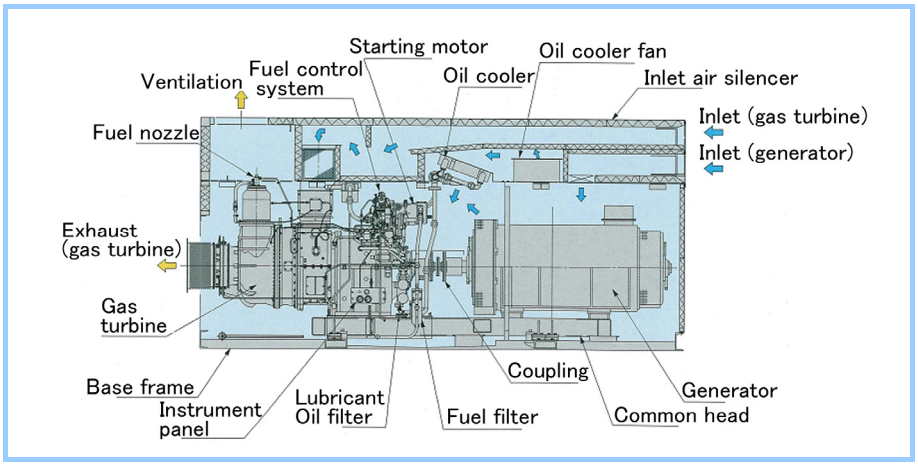

Figure 3 Appearance of the emergency gas turbine generator

3.2 Verification plan

Since the emergency electric power supply is required to have the highest quality as a safety system, we have determined to conduct new verification procedures based on the U.S. regulatory requirements so that the emergency gas turbine generator will meet the safety system requirements. This verification will be implemented according to the requirements of the Regulatory Guide specified by the NRC. The final discussion about the verification test plan is underway between MHI and NRC. We are planning to conduct a continuous load-following operation test, continuous startup test, and other necessary tests by the end of 2010.

4. Conclusion

Current statuses and plans for the HFE program and the emergency GTG verification, both of which will be used in the US-APWR, are discussed above.

Currently, the NRC is preparing an SER (safety evaluation report) in response to the DCD submitted by MHI. We will continue adopting and/or developing new technologies toward the future that can be accepted by both the NRC and U.S. industries and take the leadership in the field of I&C technologies through preparation of DCDs on the HSI system and the emergency GTG, as well as in meetings about the contents of technical reports.

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