Application of 4-Face Fuel Visual Inspection System during Outage in Nuclear Power Plant

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1. Introduction

Recently, as a measure to reduce an outage duration in nuclear power plants (NPPs), a four-face fuel visual inspection system (4-FFVIS) built in 4 cameras was introduced by Ahlberg Electronics, Sweden. The 4-FFVIS is used to inspect the external appearance of irradiated fuel assemblies in order to confirm their integrity against mechanical defects and foreign materials. Until now, however, a typical one-face fuel inspection system(1-FFVIS) has been world-widely utilized in NPPs. The 1-FFVIS requires four turns with 90 degree to inspect every face of the fuel assembly, causing a relatively long inspecting time. But the 4-FFVIS allow us to inspect every face of the fuel assembly at the same time. The inspection time with the 4-FFVIS may be less than two minutes per fuel assembly, whereas that with the 1-FFVIS is about six minutes per fuel assembly. In viewpoint of this merit, the 4-FFVIS is expected to be world-widely used in the near future.

In this paper, the technical requirements necessary to develop the 4-FFVIS as well as some improvements to complement the current 4-FFVIS are described.

2. System Description

The 4-FFVIS consists of 3 main parts: Inspection Frame, Camera & Lighting Module and Control Unit as shown Fig. 1.

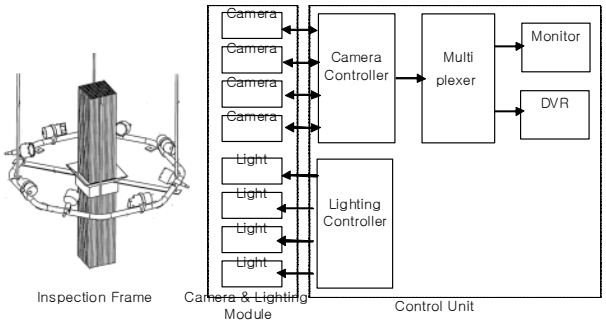


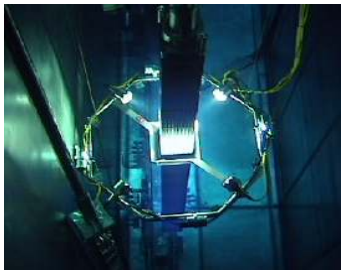
Fig 1. System Architecture of 4-FFVIS

The 4-FFVIS is installed in the fuel transfer canal or on the spent fuel lack according to facility layout condition. The inspection frame is designed differently following the location of the equipment installation, but the frame is normally composed with two parts as an underwater and upper frame. The underwater frame is to support 4 cameras and lightings, and the upper frame to handle the under water frame for installation.

Four underwater color cameras are mounted on the underwater frame, which are located at the close distance of about 0.6m to a high radioactive product, fuel assembly. The special shielding cases and angle mirrors on the camera module are applied to protect from the radiation dose. And four radiation tolerant underwater lights for illumination are equipped on the frame.

The Control Unit is designed for controlling of 4 different Camera & Lighting Modules simultaneously or respectively. This unit also distributes the video image to 4 different monitors, or with a video- multiplexer to a split screen 4-image combination into one monitor. All images are stored in Digital Video Recorder (DVR).

The Figure 2 is the inspection scene using 4-FFVIS in domestic NPP.



Inspection Frame equipped Cameras and Lightings

Control Unit

Fig. 2. Inspection using 4-FFVIS at Fuel Canal

3. Technical Requirements and Improvements

3.1. Inspection Frame

The Inspection Frame is designed basically to prevent fuel damages during its handling and installation, and easily decontaminate the radioactive substance by simple structure as possible. The total weighing of the flames is limited to protect the damage of spent fuel rack.

The radiation resistance materials are required to apply all components.

3.2. Camera & Lighting Module

In order to protect from the radiation dose, the camera are normally shielded with stainless steel radiation material. This approach is not appropriate method, since it is become one of cause increasing a total weight of frame. It is recommended to develop high radiation tolerance camera which can be used in more than $6x10^4$ Gy total absorbed dose environment (This value is estimated at 650 mm distance from the surface of the fuel assembly) and $2.3x10^2$ Gy/hr absorbed dose rate. As for lightings, the locations mounted on the frame are considered to minimize some reflect effect due to the other lights. In addition, the light with sprinkle-effect illumination is required.

The 4-FFVIS carries out the rapid 4-faces fuel visual inspection, but the inspection of the bottom of fuel assembly is additionally required to raise the examination efficiency. Therefore, one more camera or tilt function of the camera module is needed to confirm a kind of foreign material presence on the bottom nozzle of the fuel assembly.

Since all faces of fuel appearance simultaneously display on the monitor, the four different images are evaluated at the same time by one inspector. This procedure induces the mistake skipping a kind of bad images by human error. In order to complement this weak point, an automatic inspection program comparing with as-built condition as a real-time is necessary. This automatic program is developing by KNF using LabVIEW™.

4. Conclusion

The 4-FFVIS is not plentifully used in whole world NNPs, however, to increase the operation efficiency of NNP, the 4-FFVIS will be preferred by utilities, and substituted with the existing one-face camera system in the near future. As example of domestic, the 4-FFVIS was implemented at Uljin Unit 3 in 2004 firstly, and successively three more systems were introduced. But, in still initial use stage, the information including technical backgrounds will be useful to efficiency application and maintenance for the existing 4-FFVIS. And, in order to upgrade the system, some suggestions based on experiences gained during application are described in this paper.

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