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Performance Evaluation and Suggestion of Upgraded Fuel Handling Equipment for Operating OPR1000

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1. Introduction

The purpose of this study is to evaluate the performance of upgraded FHE (Fuel Handling Equipment) for operating OPR 1000 (Optimized Power Reactor) by using data measured during the fuel reloading, and make some suggestions on enhancing the performance of the FHE. The fuel handling equipment, which serves critical processes in the refueling outage, has been upgraded to increase and improve the operational availability of the plant. The evaluation and suggestion of this study can be a beneficial tool related to the performance of the fuel handling equipment.

2. Performance Test and Evaluation

The fuel handling equipment consists of various equipment performing safety functions and interlocks [1] to handle fuel assemblies safely and should satisfy the operation performance by rapidly transferring fuel assemblies. The fuel offloading and reloading between the Reactor and the SFSR (Spent Fuel Storage Rack) are performed by the RM (Refueling Machine), the SFHM (Spent Fuel Handling Machine), the FTS (Fuel Transfer System) and the Upender in the Containment Building and the Fuel Building as shown on Fig. 1.

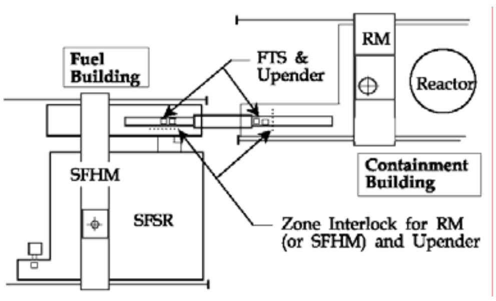

Fig. 1 Arrangement of Fuel Handling Equipment

The improvements for the fuel handling equipment under construction and in operation have been studied to increase operating efficiency. High speed motors, Motor Controllers, PLC's(Programmable Logic Controllers), Position encoders, HMI (Human Machine Interface) and interlocks in the control system have been installed to reduce the fuel handling time. The off-index operation for the RM hoist is applied during raising and lowering the fuel assembly in the open water region of the core. The simultaneous travel zones and optimal travel path operations for the bridge and trolley of the RM and the SFHM are also expanded to reduce the handling time [2]. The performance test for the upgraded fuel handling equipment should be performed during the reloading following the installation of the equipment to verify compliance with the performance criteria. This test is performed for the transfer of twenty (20) fuel assemblies during the fuel reload. Each machine of the fuel handling equipment, which consists of the RM, the FTS with the Upender and the SFHM, should be tested individually during 20 cycle periods. The average time for the 20 cycles is measured and evaluated according to the criteria as shown on Table 1. The performance test criteria stipulates that more than six (6) fuel assemblies per hour should be reloaded and a total transfer time for 20 cycles should be within 200 min.

Table 1 Performance Criteria

Reloading (FA/Hour)	Time for 20 Cycles	Level
$N \geq 6.0$	$t \leq 200$ min.	Acceptable
$N < 6.0$	$t > 200$ min.	Unacceptable

The sequence for fuel loading is organically connected and operated with the combination of three (3) fuel handling machines. At this study, the RM reloading sequences are analyzed for 20 cycles during the reloading. The one (1) reloading cycle into the core by the RM can be divided into five (5) sequences based on the travel path between the Upender and the Ractor. The detailed reloading sequences and their elapsed times for the RM off-index operation at the Reactor are summarized in Table 2. The reloading cycle for the RM starts at the Upender with the hoist down and a fuel assembly grappled. The cycle ends with the hoist down and the next fuel assembly grappled at the Upender after loading it in the Reactor. The elapsed times in the SN-1, the SN-3 and the SN-4 are determined by the RM hoist speed at the Upender and at the Reactor. The SN-3 and the SN-4 indicate that the hoist down for un-grappling a fuel assembly and the hoist up to the up-limit at the Reactor, respectively. The elapsed time of 80 sec for the SN-4 was shorter than that for the SN-3, which takes some time for an off-index loading operation in the open-water region.

Table 2 Elapsed Time for Reloading Sequences of RM

Seq. No. (SN)	Reloading Sequences for RM (Based on Off-Index operation)	Fuel at Hoist	Time (sec)
1	RM hoist down for grappling a fuel and up at Upender	Unloaded/ Loaded	119.0
2	RM move to core from Upender	Loaded	75.0
3	RM hoist down for un-grappling a fuel at Reactor	Loaded	132.0
4	RM hoist up to up-limit at Reactor	Unloaded	80.0
5	RM move to Upender from Reactor (Waiting time for upending)*	Unloaded	161.0 (90.0)
	Total One(1) Cycle Time : 9 min 27 sec		567.0

Note (*) : Based on the zone-interlock of RM and Upender

The RM hoist speed is controlled under the requirements at the slow speed zones of the SN-3 and the SN-4. The elapsed times in the SN-2 and the SN-5 are determined by the RM bridge and trolley speed between the Upender and the Reactor. Their elapsed times were measured as 75.0 sec and 161.0 sec, respectively. The SN-5 includes a waiting time of the RM bridge and the Upender vertical interlock in the containment building. In this sequence, the RM bridge usually has to wait outside the Upender area until the Upender is vertical. The cycle time of the Upender is approximately 45 sec. It means that we can save this time if the loaded FTS carriage would arrive sooner and rotate for withdrawal of a fuel assembly with the RM. To optimize the fuel handling equipment performance it would be necessary to reduce the waiting time of the RM at the Reactor side Upender.

3. Tips for Performance Improvement

Based on the evaluation of this study, we can provide some tips to increase the operational efficiency by simply modifying the components. The upgrade has been made in the drive motor of the transfer carrier and the hydraulic pumps of the Upender to enhance the operation performance at the early stage of the upgrade.

Table 3 Tips for performance improvement

Seq. No. (SN)	Tips for performance improvement	Expected reducing time
1	Application of RM hoist clear condition in unloaded condition	Modification is needed
2	(None)	(None)
3	(None)	(None)
4	Application of RM hoist clear condition in unloaded condition	Modification is needed
5	- Speed improvement of Upender and FTS carrier - Allowance of entering into the Upender in unloaded condition	- 90.0 sec - 10.0 sec
	Total reducing time for one(1) cycle : Max. 100.0 sec	

Table 3 shows the tips for further performance improvement. As shown on the SN-5 of Table 3, we can save maximum 90 sec. by increasing the speed of the Upender and the carrier. Especially, we can achieve the goal by simply modifying the upending component of the Upender at each building. In the design of interlock system, the zone interlock exists between the RM (or the SFHM) and the Upender as shown on Fig. 1. This interlock can be one of the factors to determine the performance of the upgraded fuel handling equipment. In case of having this zone interlock, the Upender is only allowed to rotate when the RM (or the SFHM) is located outside of the Upender zone which is certain distance from the Upender at each building. We found that there were conservative factors for the operation in an unloaded condition with the Upender vertical interlock and the hoist clear interlock. By eliminating the Upender vertical interlock and using the hoist clear interlock in the unloaded condition between the RM (or SFHM) and the Upender, it is expected to save minimum 10 sec with the same fuel safety margins. As mentioned in the SN-1 and SN-4, the elimination of the Upender vertical interlock system can be introduced for the RM hoist clear condition in an unloaded condition. But it requires some modification on the components of the hoist box and the grapple for the RM. We can save minimum 4 hrs for the full core reloading by simply increasing the speed of the Upender and the carrier and eliminating the Upender vertical interlock.

4. Conclusion

The performance of an upgraded fuel handling equipment for operating OPR 1000 (Optimized Power Reactor) is evaluated using the measured data during the fuel reloading and some tips are provided to enhance its performance. As the results of this study, increases of the operational efficiency can be achieved by simply modifying the components and eliminating of the Upender vertical interlock system. We can save minimum 4 hrs for the full core reloading

REFERENCES

[1] ANSI/ANS-57.1, Design Requirements for Light Water Reactor Fuel Handling Systems, 1992 (Re-affirmed 2007).

[2] S. G. Chang, et al, Performance Criteria and Evaluation of Upgraded Fuel Handling Equipment for Operating OPR1000, Korean Nuclear Society Spring Meeting, 2009.