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Integrated Head Area Design of KNGR to Reduce Refueling Outage Duration

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Abstract

In the design of KNGR (Korea Next Generation Reactor), we believe that economy is one of the most important factors to be considered. Thus, we reviewed and evaluated the consequences of designing the head area into an integrated package from an economical point of view. The refueling outage durations of the nuclear power plants currently in operation in Korea, some having and others not having integrated head package, are compared. This paper discusses the characteristics of head area design and the critical design issues of KNGR head area to evaluate the effect of the head area characteristics on the outage duration

1. Introduction

The KNGR project for developing nuclear power plant (NPP) having 1,300MW electric power output is on its basic design stage. KEPRI (Korea Electric Power Research Instutute), the project managing organization, selected KOPEC (Korea Power Electric Company) as the main contractor of the project. Thus, KOPEC has been doing basic design since January 1997.

In the design of KNGR, the most significant factors that should be considered are the safety and economy of the plant. To improve the safety and economy of the KNGR, new design features relevant to overhaul such as IHP (Integrated Head Package), QOBF (Quick Opening Blind Flange), PPS (Permanent Pool Seal) have been being reviewed, and the feasible features will be adopted to KNGR design. The minimization of the time necessary to the overhaul has been one of our major concerns to economize the maintenance operation of NPPs, thus many efforts have been made toward this objective[1-7]. The reports[3-7] on the overhaul which have been published whenever there were overhaul maintenance show our concern about that.

Among the several new design features that we mentioned above, we focus, in this paper, on the design of integrated head area because its consequences on the overhaul is the greatest. In the ALWR (Advanced Light Water Reactor) URD (Utility Requirements Document)[8] revision 7 at 4.3.5.1, an integrated reactor vessel head package is recommended as part of the reactor design. As a rationale of recommending IHP, it says "the use of an integrated head approach significantly reduces the amount of critical path time required to access the reactor vessel internals." IHP is defined to be "consolidation of the head lifting rig, lift columns, missile shield, control rod drive mechanism (CRDM) into an one package component design." In the same URD at 1.5.2, there is a description on refueling outage length. It says "limit the outage duration for refueling activities to not more than 17 calendar days for a 24 month operating cycles." The 17 day outage duration is based on the following assumptions :

- The activities which must be performed each and every time the reactor is refueled should be included. Test activities such as removing the reactor vessel lower internals of a PWR, replacing control rods or blades, and inspecting reactor vessel internals.
- The plant personnel could work 24 hours a day with overlapping shifts.
- Shared plant equipments such as polar crane are always available for refueling activities.
- Experienced operators shall be engaged in refueling.

To meet 17 day outage duration, the KNGR project team decided to design the head area as an integrated package. In Chapter 2, we will consider the influence of integrated head area on refueling outage by comparing the overhaul records of ordinary NPPs having no integrated head and Ulchin #1 which has some integration characteristics. In Chapter 3, some characteristics of the head area design will be presented.

2. The Overhaul of the Korean Nuclear Power Plants

During the overhaul of NPPs, inspection and maintenance of the steam generators and turbines as well as refueling is done at the same time. The previous overhaul records show us that each power plant has different schedules, but the main critical path operations such as reactor assembling, reactor disassembly, fuel extraction and fuel rearrangement appear the same in all the time tables. The critical paths related to the *refueling, steam generator inspection and low pressure turbine* maintenance are shown in Fig. 1. Among the refueling outage duration, the time taken for reactor disassembling, fuel extractrion, fuel rearrangement, and reactor assembly could be reduced by modifying the reactor and equipment design.

Fig. 1 shows the critical path of the overhaul of Ulchin #2 on March 1997. In this figure, the duration necessary for the above mentioned 4 operations is about 17 days in 48 days of critical refueling time. We can see from this figure that the total duration of overhaul is affected by not only the refueling but also inspection and maintenance of steam generator and turbines.

Fig. 2 shows the time taken in day for assembly and disassembly of Ulchin #1 compared to Kori reactors. From this figure, we could infer that Ulchin #1 is most effective in its design from the refueling outage point of view. The Kori reactors were designed by Westinghouse, however Ulchin #1 and #2 were designed by Framatome. Ulchin #1 and #2 have several design features : the head area is designed somewhat as an integrated package and more cranes and tools are available for the overhaul.

The operators of NPPs have been making great effort to reduce the overhaul maintenance time, but the effort could not avoid the limitations caused by the plant equipments design itself. That is why we should change head area design.

The investment necessary to construct a NPP is about 2 trillion won. Assuming the annual interest rate of 10 percent, the financial burden per day for 2 trillion won would be more than 500 million won. Assuming 1 refueling per year and life expectancy of NPPs to be 30 years, there will be 15,000 million won's saving by shortening a day of the overhaul.

3. An Integrated Head Area Design

Nuclear Power Plants with light water reactors require refueling on a regular basis. Prior to refueling, the reactor vessel head must be removed so that the spent fuel rods can be replaced with the new fuel rods inside the reactor core. In a typical plant arrangement a series of operational steps must be followed before the reactor vessel head is removed from the reactor vessel. These steps must be performed prior to de-tensioning the reactor closure studs. These steps include but not limited to :

① Remove and store heavy concrete missile shields
② Remove and store the control element drive mechanism (CEDM) cooling ducts
③ Remove the seismic restraints
④ Disconnect the CRDM power and instrumentation cables at the top of the CRDMs and store
⑤ Install the reactor head lifting rig tripod
⑥ Remove cable trays and cables running from the reactor head to the operating deck or walls
⑦ Disconnect any reactor head vent or any reactor vessel level detector lines
⑧ Install temporary lead shield blankets around the vessel head area (if necessary).

The procedure also requires the reactor closure studs, nuts, and washers be removed from the reactor closure and placed in storage racks during preparation for refueling. The storage racks are then removed from the refueling cavity and stored at convenient locations on the containment operating deck prior to reactor head removal and refueling cavity flooding. This way the reactor closure studs are never exposed to the borated refueling cavity water. Also, the stud holes in the reactor flange are sealed with special plugs before removing the reactor head, thus preventing leakage of the borated refueling water into the stud holes.

When reinstalling the cables and hardware, the above steps are reversed.

All the steps identified above significantly contribute to the refueling cost which include personnel man-hours, refueling outage critical path time, radiation exposure, and potential human errors. Also, the removed parts consume a large amount of the available storage space inside containment thereby having a potential for increased level of contamination. In addition, the polar crane will be dedicated to the above process and consequently limiting its availability for other handling operations inside the containment.

To minimize the operational steps, down time, radiation exposure and eventually the outage cost, the various new designs have been proposed by different reactor vessel manufacturers. One of the new designs includes developing an integrated head package in a modular form which can be detached from the reactor vessel in much less number of steps than identified above. The reduced number of steps are as follows :

① Remove the seismic restraints
② Disconnect the instrumentation cables at connector plates
③ Remove the cable tray and cables
④ Disconnect any head vent or reactor vessel water level indicator lines

When reinstalling the cables and hardware, the above steps are reversed.

Even though the cost savings are not guaranteed by the new design, some manufacturers have demonstrated a significant cost savings with the IHP design.

For the development of IHP design, a US engineering company called Advent is selected as a co-worker, and the contract will be signed soon. KEPRI and KOPEC are jointly participating in the project, and the duration of the project is 12 months. The reason of our choosing the Advent is that they have many experiences on the design modification of the US NPPs.

The joint design works of IHP include the followings :

- Data collection and review
- Develop design criteria
- Design of cooling shroud
- Design of lifting system
- Design of fans and hoist system
- Design of head area cable system

There are several registered US patents on IHP design. Westinghouse's patent 5,384,812 titled "Integrated Head Package Cable Carrier for a Nuclear Power Plants" is an example. The patented cabling system is shown in Fig. 3. This patent shows that integrating the HACT (Head Area Cable Tray) into IHP is very critical issue.

On account of the increase in load of head area, installation of a seismic supporter is the most important design requirement of IHP. The load of reactor head area will be increased a lot as the integrated design of HACT, missile shield, lifting system, and fans and hoist system. Thus the seismic supporter should be included to insure safety against earthquate of 0.3 g. And the best location of supporters will be decided based on the mode analysis of CRDM.

Fig. 4 shows the schematic diagram of IHP. In this figure we disregarded the scaling factor to show the details that we should consider during the design. We should decide the location and shape of connector plate which enables easier attachment and detachment. Another decision should be made whether the Lift Rig Assembly and Missile Shield will be included in IHP or not. Arrangement of many equipments in head area is also very important that should be decided during the design. And IHP design should permit the access of multi-stud tensioner.

As the IHP project of KNGR is in its early stage, general concepts several design features that should be decided during the design are presented in this paper. The basic design of IHP development will be completed in the end of next year, and the. final design is scheduled after that.

4. Conclusions

The comparison study of the overhaul durations of Ulchin #1 and other Kori NPPs shows that the overhaul time could be reduced by integrated head area design. The time taken for reactor assembly and disassembly of Ulchin #1 is 8.8 days compared to the Kori NPPs' average duration of 15.37 days.

The main advantage of designing the reactor head area as an integrated package is decrease in overhaul duration. Another benefit of shortened overhaul duration is that the plant operators may have less dose rate.

Our conceptual study in chap. 3 showed that the decrease in number of steps necessary for the

NPP having IHP compared to that of NPP having no IHP is remarkable. The actual steps may vary depending on the specific IHP design, but it would be almost similar.

The actual IHP design is underway as a joint development among KEPRI, KOPEC and Advent. Our major concern is how to develop our own IHP design without impringing the relevent patent rights of Westinghouse and ABB-CE.

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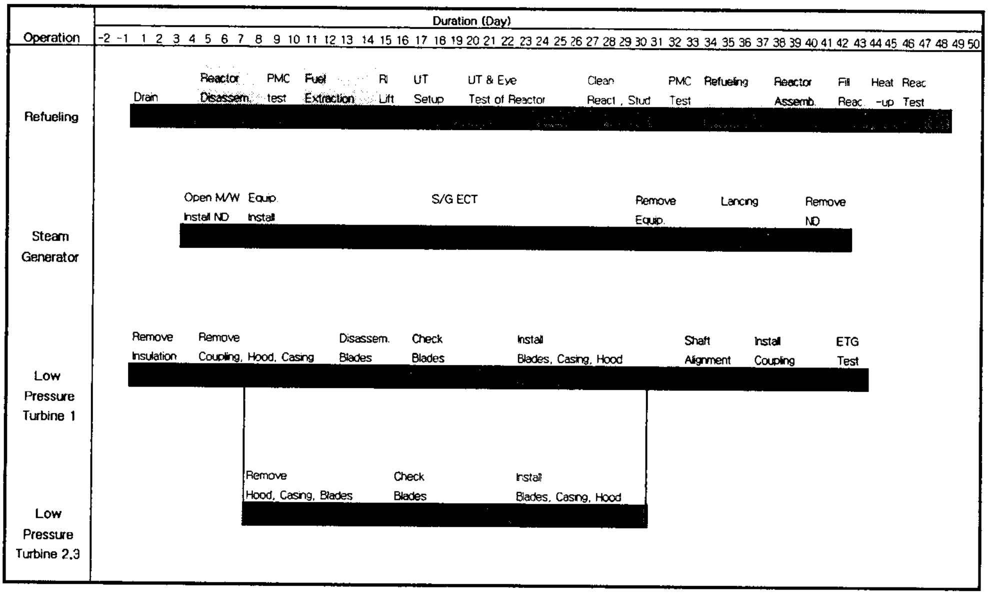

Fig. 1 Critical Path of the 7th Overhaul of Ulchin #2 (March 1997)

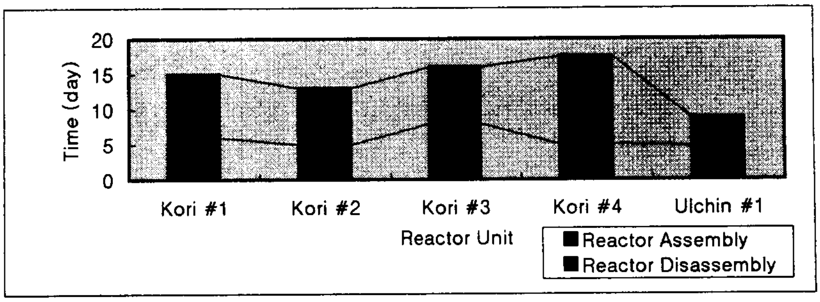

Fig. 2 Comparison of Reactor Assembly and Disassembly Time

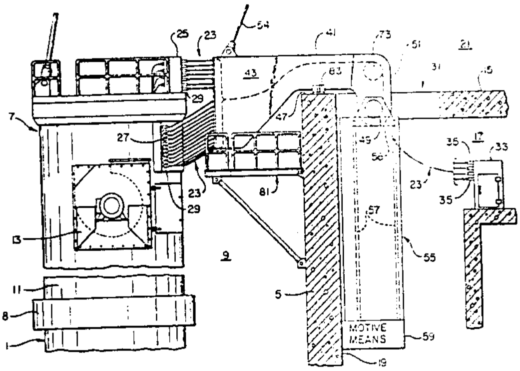

Fig. 3 Sample IHP Design of Westinghouse

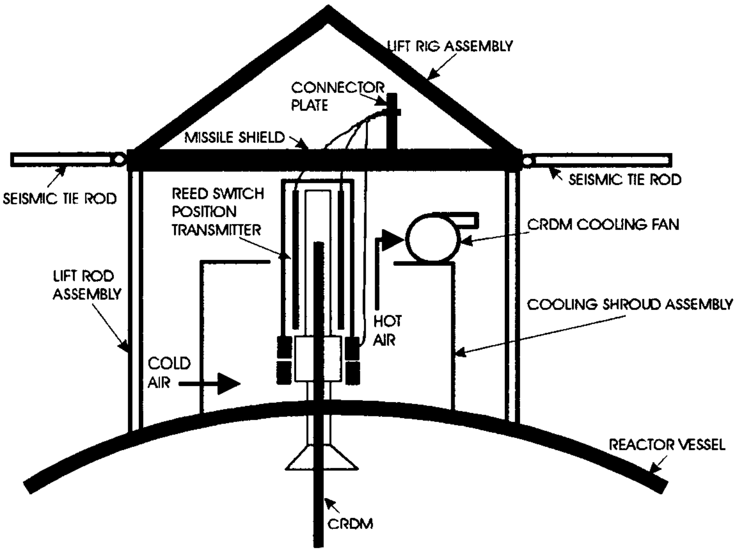

Fig. 4 A Schematic Diagram of IHP