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Performance Evaluation Technology for Air Operated Valves in NPPs

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1. Introduction

A power-operated valve (motor-operated valve; MOV or air-operated valve; AOV) is an essential element to control the piping flow in a nuclear power plant(NPP). In fact, the operational failure of a safety-related AOV can have catastrophic results. Therefore, it is necessary that the operability of safety-related AOVs should be ensured in the design basis conditions. To ensure the design-basis operability of safety-related AOVs in NPPs and to meet the requirements of In-Service Testing regulation specified in Ministry of Science & Technology (MOST) issue 2004-14, the performance evaluation technology for AOVs was developed by end of 2006. This paper introduces an efficient technology to evaluate the performance of AOVs under design basis conditions. The technology to be utilized includes the methods of Design Basis Review (DBR), diagnostic testing under both static and dynamic conditions, and final operability evaluation considering DBR and testing results.

2. Selection of AOVs for Evaluation

This evaluation is to be performed on all key AOVs of Nuclear Power Plants in Korea, except ducts and dampers. But at the first, AOVs for evaluation were selected among safety-related AOVs within In-service Testing Plan of each plant based on MOST issue 2004-14. For non-safety related AOVs, the performance results of Maintenance Rule will be reflected in the evaluation in the future and AOVs of the important function will be classified as the subject of evaluation. In general, nuclear power plants have a large population of AOVs with varying degree of safety-significance. Each plant shall determine the safety-significance of the AOVs. The AOVs within the evaluation program are classified into two categories.

Category 1 : AOVs that are safety-related, active, and have high safety-significance

Table 1. Selection of AOVs for Evaluation

Plant	Active Valve	Passive Valve	Total	Selection Valve
Kori1	41	60	101	50
Kori2	74	80	154	78
Kori3,4	86	112	198	118
Yonggwang1,2	86	122	208	118
Yonggwang3,4	76	24	100	88
Yonggwang5,6	84	28	112	100
Wolsong1	85	18	103	91
Wolsong2,3,4	393	60	453	417
Uljin1,2	186	32	218	192
Uljin3,4	84	28	112	100
Uljin5,6	84	28	112	100
Total	1,279	592	1,871	1,452

AOVs that are non-safety-related, active, and have high safety-significance

Category 2 : AOVs that are safety-related, active, and do not have high safety-significance

On the In-service Testing Plan of Korean plants, AOVs are a total of 1,871 as shown in table 1. According to the selection method of AOVs for evaluation, AOVs for evaluation were selected provisionally a total of 1,452. Table 1 shows the AOVs selection result of the nuclear power plants.

3. Design Basis Review

DBR consists of evaluation processes for system design-basis review, required thrust/torque analysis, weak link analysis, actuator performance analysis and operational margin analysis.

The system design-basis review is to grasp valve/actuator design and operation information, and to calculate fluid differential pressure around the valve disc. Required thrust and torque analysis is to calculate the desired force during the valve stroking. During the valve actuation, various loads are occurred as below, valve disc and stem weight, fluid differential pressure load, packing and stem frictional force, fluid piston effect, etc.. Required thrust and torque analysis is made considering these loads. Weak link analysis is made to determine a limited value of endurable ability about main component of valve and actuator during the valve stroking, and it is also to analyze the structural integrity through the verification. Actuator output thrust should overcome attendant force during the valve stroking and be analyzed for the actuator output capability. The minimum actuator output thrust/torque is calculated to determine the capability of stroking a valve in the open and close directions and of maintaining the valve full open. Evaluation of actuator output capability depends on the type of rising stem valve with which the actuator is coupled. When coupled with direct acting valves, the actuator output capability is evaluated at two locations, as the actuator rod is approaching the fully extended position (for closing the valve) and as the actuator rod is approaching fully retracted position. Operational margin analysis is to compare the actuator output thrust/torque with the required thrust/torque. For rising stem AOVs, operational margin should be evaluated for four points (initial closing, full closing, initial opening, full opening). For quarter turn valves, capability margin should be evaluated at each angle of the stroke. Figure 1. shows the flowchart of design basis review.

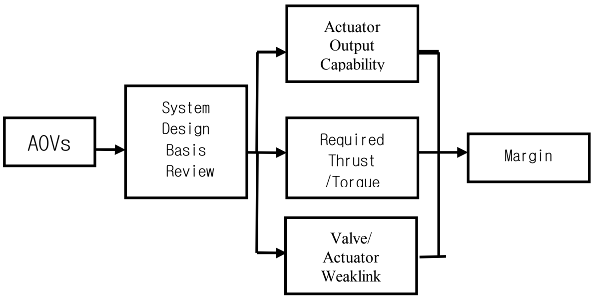

Figure 1 Flowchart of AOV Design Basis Review

4. Diagnostic Testing

Three main types of AOV testing are utilized, bench set testing, static testing and dynamic testing. One of the fundamental purposes of testing an AOV is to confirm by measurement that the AOV will perform its desired functions under its design basis condition. During the valve stroking, required thrust/torque, air pressure supply to actuator and spring preload are measured by diagnostic testing device. Figure 2 shows the AOV test facility.

Figure 2 AOV Test Facility

5. Performance Prediction Methodology

Testing is the most correct method for performance evaluation of AOVs in design basis condition. But it is difficult to test the valve under the condition in nuclear plant. Testing can be considered as an additional burden to utility. Performance prediction method is to predict the required thrust of operating valves without the testing. The valve operation condition can be considered in this method and the various coefficients from valve testing results are used for the evaluation. KVAP, the Kalsi Valve & Actuator Program, is one of the soft wares to efficiently perform reliable design basis calculations for all common types of rising stem valves and quarter-turn valves. Figure 3 shows the input data screen of KVAP.

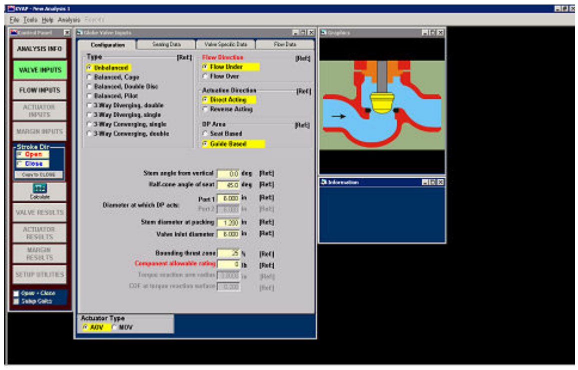

Figure 3 Input Data Screen of KVAP

6. Conclusion

The performance of valve is evaluated through design basis analysis, diagnostic testing and performance prediction methodology. Finally reflecting the above results, the last operational margin is determined by overall evaluation. If operational margin of a valve is not sufficient, corrective actions for margin improvement of the valve are taken. The performance evaluation of AOVs and the corrective actions taken on the valves make it possible that maintaining safety margin of key AOVs in NPPs is confirmed again. The design basis performance evaluation was started for the AOVs in all plants in Jan. 2007 and will be completed in Jul. 2010. In addition, it is believed that this compressive AOV evaluation process developed in Korea is the first case in the world. And performance evaluation on AOVs of secondary systems is one of the future works to be considered.

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