Screening Analysis Procedures of Relay for Seismic PRA

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1. Introduction

In order to evaluate the safety of a nuclear power plant during a seismic accident it is necessary to evaluate the seismic performance of structures and equipment installed in the nuclear power plant. In the seismic probabilistic risk assessment (SPRA) for nuclear power plants in the 1980s, it was assumed that the malfunction of the relay could be recovered by the operator without analyzing the malfunction of the relay [1]. However, as a result of the research conducted by the Nuclear Regulatory Commission, it was found that if the recovery of the operator for the main relay is not performed properly, it has a very high probability of causing core damage [2].

According to IEEE Standard 313[3], a relay is defined as an electrical device designed to cause a change such as contact action in the related electrical control circuit in response to an input signal under a specific condition.

In general, there are thousands of relays in a nuclear power plant, and reflecting all these relays in a probabilistic risk analysis model requires considerable time and manpower. Therefore, it is necessary to select and analyze the relays related to the safety shutdown of the power plant among the relays. In this paper, we intend to describe the analysis procedure for selecting essential relays used in the nuclear power plant system that should be operated during or after the earthquake to mitigate accidents.

2. relay classification

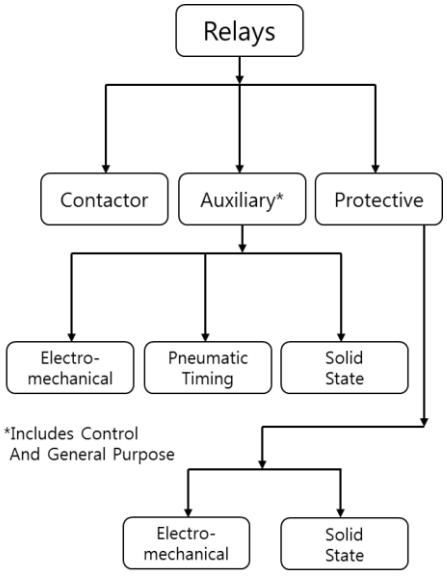

Fig. 1. Relay classification

The input signal is usually an electrical, but may be a combination of different types of signals, such as a physical or a thermal signal.

Relays are classified into three general categories as shown in Fig 1.

The first category is designated as auxiliary relays. An auxiliary relay is one whose function is to assist another relay or control device in performing a general function by supplying supplementary action. Typical auxiliary relays will be considered to include general purpose, control, blocking, closing, lockout, seal-in, and other logic or control related relays.

The second general group of protective relays. A protective relay is one whose function is to detect abnormal or dangerous conditions with in power apparatus and systems and to initiate appropriate control action. Protective relays are typically classified according to their input quantities, operating principle, or performance characteristics. Typical protective relays include over-current, under-voltage, distance, ground, phase, and directional. Protective relays are subdivided into electromechanical and solid state relays.

The third general relay category is contactors. A contactor is considered to be a heavy-duty relay which may carry several tens of amps of current. It is distinguished from a typical breaker (as used in switchgear) in that its contacts are moved a solenoid type mechanism rather than charged springs.

In addition, there are devices with contact sensor switches or manual control switches used in relay control circuits. However, most of these devices are not classified into a special relay category because they are often checked together during the relay verification test.

3. Relay failure mode

The following is a summary of relay failure modes that can cause abnormal operation of the device due to relay malfunction due to earthquake.

- Relay malfunction: Open/close due to valve malfunction, start/stop due to pump malfunction, and relay failure causing open/close due to breaker malfunction
- Failed to operate relay: In the event that a device, such as a valve or breaker, fails to operate even after receiving a signal.

In general, the relay is stable if the contact interval of the switch is long as shown in Fig. 2, but if it is repeated within an extremely short period of time, it may cause a malfunction, such as maintaining the contact of the switch.

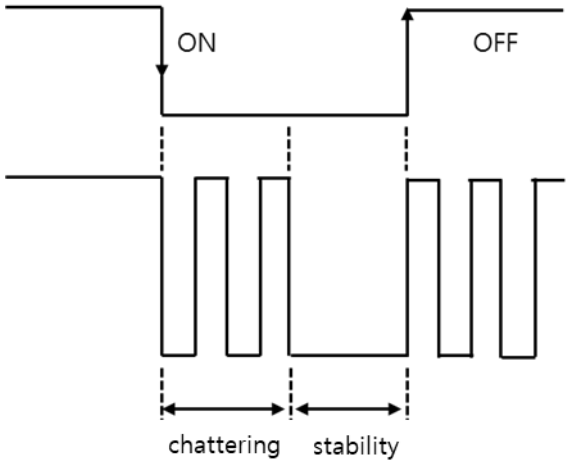

Fig. 2. Example of relay malfunction signal

4. Essential relay screening procedure and assumptions

According to the EPRI 3002004396[4], essential relays can affect the power plant safety shutdown system by causing device malfunction due to chattering by change of state.

In order to identify the essential relays to be operated in earthquake. Through the screening process, relays that are not related to the power plant safety stop function or have sufficient seismic fragility in the event of an earthquake can be excluded.

- Function selection: Select a relay that functions as necessary to maintain a high-temperature stop state for at least 72 hours after a Safe Shutdown Earthquake occurs. Related functions include reactivity control, decay heat removal, reactor coolant pressure and coolant inventory maintenance, monitoring and control functions.
- System Selection: Select the system considering the system that may cause an accident due to the system failure.
- Equipment selection: Select specific equipment in the system to perform the required function.
- Failure mode and effect analysis: Review the results of relay malfunction through FMEA (Failure Modes and Effects Analysis). Through this, among the selected functions, systems, and relays in the device, those that affect the accident are selected.
- Based on NP-7148[5], If the operator recognizes the status of the system and equipment as an alarm lamp and takes adequate immediate action within 30 minutes to one hour, or if there is a separate recovery procedure, it should be screened out.

The selected relay according to the above screening procedure is classified as essential relay and is subject to seismic performance evaluation.

The criteria and assumptions for relay evaluation are as follows.

- Select relays that cause malfunction when an earthquake occurs, even if the relay operates normally after an earthquake
- If a relay malfunction does not affect the safety function, it can be screened out.
- It is assumed that relay malfunction occurs when opening or closing the relay lasts longer than 2 msec.[5] The Generic Equipment Ruggedness Spectra(GERS) [6] used in the relay screening procedure is based on a test using a contact failure criterion of 2 msec or less.
- Mechanical contact malfunctions such as control switch contact and limit switch contact are not considered when an earthquake occurs.
- -Solid state relays without mechanically moving parts do not require seismic performance evaluation.
- According to the seismic test requirements of ANSI/IEEE C37.98-1978[6], relays that have seismic resistance above 6.0g ZPA can be screened out

Relays selected based on the above selection procedures and assumptions are classified as essential relays and need to seismic performance evaluation.

5. Relay screening analysis result

As a result of based on the selection procedure in chapter 3, the essential relay that generate 2ms chattering was selected lock out relay and seal-in relay.[4] On the other hand, the mainly screened-out type is solid state relay and relay that activates the alarm

6. Conclusions

In this paper, we investigated the relay screening procedure for seismic probabilistic risk analysis. After selecting the essential relays to operate in the event of an earthquake a failure modes and effects analysis has performed.

When classifying relays, the types of relays are largely classified into auxiliary relays, protective relays, and contactor relays. Among them, the one that can cause abnormal operation of the device due to an earthquake should be selected, which has malfunction due to the contact chattering of a contactor relay.

As a result of relay screening analysis, the selected relays are lock out relay and seal-in relay.[4] The selected relay is quantitatively evaluated by the cabinet based seismic fragility assessment. The failure probability of the relay is reflected in SPRA fault tree through the seismic fragility assessment result.

However, there are currently no data related to relay capacity in Korea, so further research and construction are needed.

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