A Study on the Improvement of Restart Logic for the Essential Service Water Pump in Hanbit NPP Units #3 and #4

Gyu-yong Jang, Man Gyun Na*
Dept. Of Nuclear Engineering, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju, Korea
*Corresponding author: magyna@chosun.ac.kr

1. Introduction

The Essential Service Water (ESW) system performs a function to assist the Component Cooling Water (CCW) system with removing heat from the main equipment in Hanbit Nuclear Power Plant (NPP) Units #3 and #4. During the normal operation of the NPP, only one Essential Service Water Pump (ESWP) in each train shall be operated and the same is applied in the event of a Loss of Off-site Power (LOOP). However, if a LOOP occurs when two ESWPs are running simultaneously during a process of the ESWP swap operation, two ESWPs will be restarted at the same time by the load sequence signal after the Emergency Diesel Generator (EDG) starts. This situation is a hazard for the safe operation of the NPP because it can affect the normal operation of the EDG by overloading.

We would like to introduce the study results on the improvement of control logic which makes only one ESWP in the train restarted when a LOOP occurs in all operation condition of Hanbit NPP Units #3 and #4.

2. Status and Analysis

In this section, the concept of the control logic for the ESWP is described and the problem of the control logic is presented.

2.1 The concept of the ESW system

The ESW system, which is an once-through cooling water system, supplies seawater for cooling the Component Cooling Water (CCW) heat exchangers. The ESW system consists of two independent trains and each train has two 100% capacity ESWPs. During all mode of the NPP operation, one ESWP in each train operates while the other ESWP remains on standby. The ESWP operation during the NPP startup, shutdown and accident conditions is basically the same as that during the normal operation.

2.2 The requirements of the system functional description

The System Functional Description (SFD) presents design objectives and key criteria, including functional requirements for each system of the NPP. According to the SFD for the EDG system [4], in the event of a LOOP the undervoltage relay trips the Startup Transformer (SUT) main breaker and actuates the EDG. Once the EDG reaches the rated voltage and frequency, the equipment that has been stopped by the LOOP are restarted automatically by the load sequence signal with pre-determined set time interval. At this time, only one of two ESWPs in each train shall be restarted at a time. The set time interval and requirements of load sequence signal for each equipment are shown in Table 1.

Table 1. The load sequence signal and the set time interval

Step	Time	Equipment	Remarks
1	0 sec	Transformer	-
2	5 sec	HPSI Pump	-
3	10 sec	AF Pump	-
4	15 sec	CS Pump	-
5	20 sec	LPSI Pump	Injection mode
		RC Fan Cooler	-
6	25 sec	CCW Pump	1 out of 3 pumps in each train, at a time
7	30 sec	ESW Pump	1 out of 2 pumps in each train, at a time
8	35 sec	ECW Chiller	-
9	40 sec	CCW Pump	1 out of 3 pumps in each train, at a time

2.3 The concept of the control logic for the ESWP

The control logic program for the ESWP in Hanbit NPP Units #3 and #4 is loaded on the Erasable Programmable Read Only Memory (EPROM) of the control card in the Interposing Logic System (ILS). Fig. 1 gives a concept for the control logic for the ESWP.

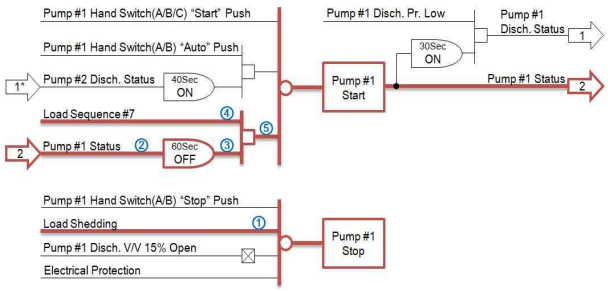

Fig. 1. The control logic for the ESWP

The operator can manually start or stop the ESWP using the hand switch on the Main Control Board (MCB) or Remote Shutdown Panel (RSP). The ESWP is also automatically started when the discharge pressure

of the other ESWP in operation is low. Also, the ESWP is stopped when electrical protection conditions are detected. If a LOOP occurs when one ESWP is running, the ESWP is stopped by the load shedding signal and then, restarted after 40 seconds, where 40 seconds is the summation of 10 seconds for the EDG start-up and 30 seconds for the input time of the load sequence signal. Fig. 2 gives a timing chart for the control signals. The 60 sec OFF delay circuit within the control logic ensures that only one ESWP that was previously running is restarted. This action satisfies the requirements of the SFD.

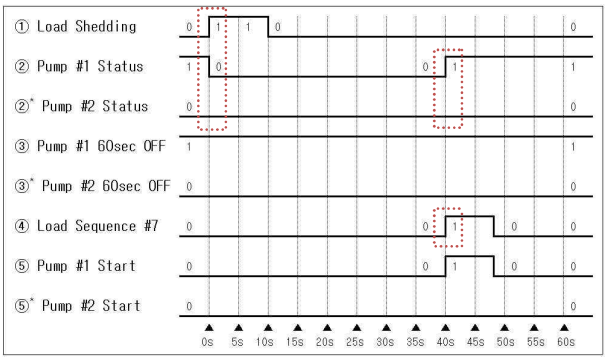

Fig. 2. Timing chart for the ESWP control signal in case of the LOOP during only one ESWP is running in the train

2.4 The problem analysis

As the fatigue of the ESWP may increase in case only one ESWP is operated for a long time, the operating ESWP is periodically swapped to the other ESWP on standby in the train. The procedure for the ESWP swap operation is as follows [6]:

① The MCR operator checks that one ESWP in the train is in operation and the other ESWP is on standby.
② The MCR operator starts the standby ESWP.
③ The local operator checks the condition of the newly started ESWP in the field.
④ The MCR operator stops the ESWP that was in operation previously.

After examining the ESWP operation history through the Plant Information (PI) program it has been confirmed that two ESWPs in the train were running simultaneously for one to four minutes during the swap operation. Refer to the PI history in Fig. 3.

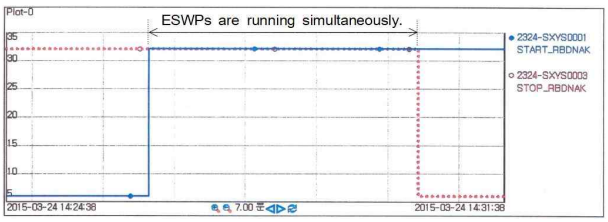

Fig. 3. The PI history of ESWPs' simultaneous running

If a LOOP occurs when two ESWPs in the train are running simultaneously, all ESWPs will be stopped by the load shedding signal and then restarted at a time by the load sequence signal. Fig. 4 gives a timing chart for the control signals. This situation is caused by the 60sec OFF delay circuit which provides the restart signal to both ESWPs in the train. This situation is a hazard for the safe operation of the NPP because it can affect the normal operation of the EDG by overloading.

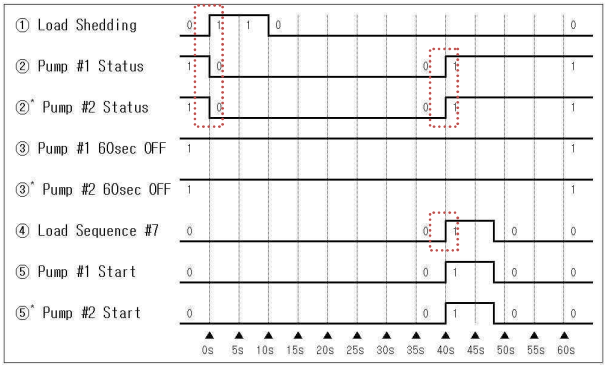

Fig. 4. Timing chart for the ESWP control signal in case of the LOOP during two ESWPs are running simultaneously in the train

3. Methodologies and Improvements

In this section, the methodologies and improvement of the control logic for the ESWP restart are described.

3.1 The goal of the improvements

In order to ensure that the improved control logic meets the requirements of the SFD during all modes of the NPP operation, three goals have been set as follows:

① If a LOOP occurs when only one ESWP is running, one ESWP that was previously running shall be restarted.
② If a LOOP occurs when two ESWPs are running simultaneously, one ESWP that was started later shall be restarted.
③ If a LOOP occurs when both ESWPs remain in the stop condition, all ESWPs shall not be restarted.

For reference, the goal number ② was not expected to be achieved in the previous control logic for the ESWP.

3.2 The concept of the memory circuit

In the previous control logic for the ESWP, the 60sec OFF delay circuit remembered the ESWP's own state only. So, the improved control logic introduced the reset priority SR-latch as a memory circuit to fix the function to remember the state of both ESWPs in the train. Fig. 5 shows the legend and configuration of the reset priority SR-latch.

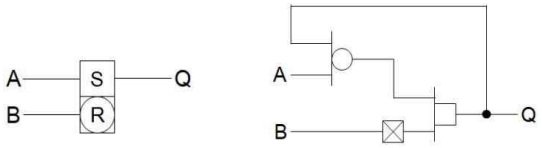

Fig. 5. Legend and configuration of the reset priority SR-latch

The output value of the reset priority SR-latch changes when the signal is inputted into the latch. Also, even if the signal is not inputted into the latch, the existing output value is still maintained. Table 2 shows the truth table for the latch.

Table 2. The truth table of the reset priority SR-latch

Input		Output
A	B	Q
0	0	Q
0	1	0
1	0	1
1	1	0

3.3 Improvements

In order to improve the control logic for the ESWP, the operation status signal of both ESWPs in the train is inputted respectively to the Set and Reset of the latch. The sequence in which both ESWPs are stopped is applied to the logic of the latch by introducing the NOT circuit to the ESWPs operation status signal. In addition, the 0.5sec ON Delay circuit was added so that the signal transport time from the switchgear in the field to the control card in the MCB would not affect the output value of the latch. Fig. 6 gives a concept for the improved control logic for the ESWP.

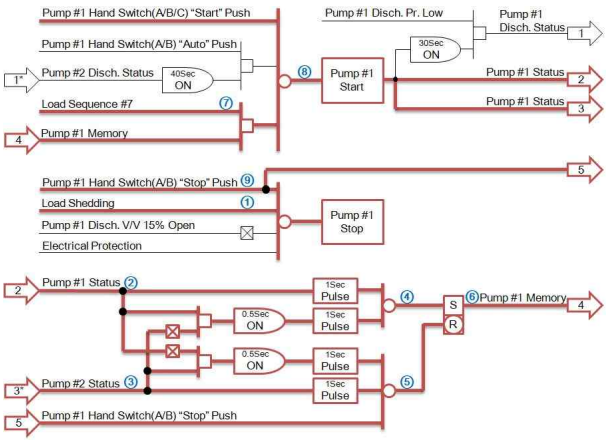

Fig. 6. The improved control logic for the ESWP

3.4 Results

It has been confirmed that if a LOOP occurs when two ESWPs in the train are running simultaneously, all running ESWPs are stopped by the load shedding signal and then only one ESWP that was started later is restarted by the load sequence signal. Refer to the timing chart in Fig. 7.

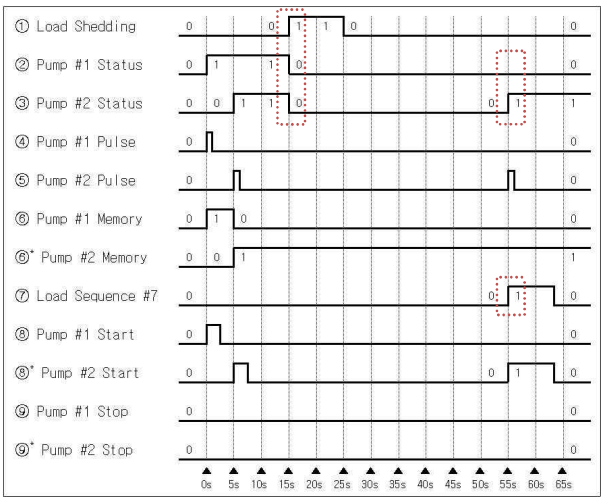

Fig. 7. Timing chart for the ESWP control signal in case of the LOOP during two ESWPs are running simultaneously in the train

4. Conclusions

This study was conducted to solve the problem of malfunctioning the ESWPs restart in case a LOOP occurs when two ESWPs in the train are running simultaneously. It had been demonstrated through the analysis using timing charts and the functional test in the ILS simulators that the function of the improved control logic meets the requirements of the SFD. The improved control logic program for ESWPs was loaded on the EPROM of the control card in the ILS. Consequently, this improvement is expected to make a safer and more reliable system of Hanbit NPP Units #3 and #4.

REFERENCES

[1] KHNP Hanbit training center, System manual for Hanbit NPP Units #3 and #4, (2015)
[2] KHNP Hanbit NPP Units #3 and #4, Design change documentation of the start logic for the ESWP, (2016)
[3] KOPEC, 9-462-N403, System Functional Description for the ESW system, (1992)
[4] KOPEC, 9-591-M403, System Functional Description for the EDG system, (1995)
[5] KHNP Hanbit NPP Units #3 and #4, Surveillance test procedure for ESWPs and safety related valves (Revision 18), (2019)
[6] KHNP Hanbit NPP Units #3 and #4, System operation procedure for the ESW system (Revision 9), (2018)
[7] KHNP Hanbit NPP Units #3 and #4, System operation procedure for the EDG system (Revision 10), (2019)