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Improvements of the Main Feed Water Pump Speed Control Methods in Hanbit Nuclear Power Plant Units 3 and 4

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1. Introduction

The main feed water pump (MFWP) control facility of Hanbit nuclear power plant (NPP) units 3 and 4 was upgraded from an analog facility to a triple modular redundant (TMR) digital facility to minimize transient conditions caused by the single signal failure and old equipment failure in 2011. However, due to the inefficient speed control logic of the control facility, the MFWP speed was fluctuated irregularly. These speed fluctuations may cause mechanical wear and failure of the MFWP. In addition, the speed sensors detecting the MFWP speed are located inside the pump housing of the MFWP. So it is difficult to repair or replace them during the operation period. If one speed sensor is failed, it is necessary to overhaul the MFWP. Therefore, we would like to introduce the research results regarding the improvements of the MFWP speed control methods in Hanbit units 3 and 4.

2. Improvements of the MFWP speed fluctuations

In this section, the causes of the MFWP speed fluctuations in Hanbit units 3 and 4 are described and we introduce the improvements and results.

2.1 Concept of the MFWP speed control

In order to control the MFWP speed, the MFWP control facility uses the deviation of the speed demand signal and the MFWP actual speed signal. However, because the deviation of two speed signals is basically very large, a high dead band (45rpm) is used to avoid the fluctuations. Fig. 1 shows its brief explanation.

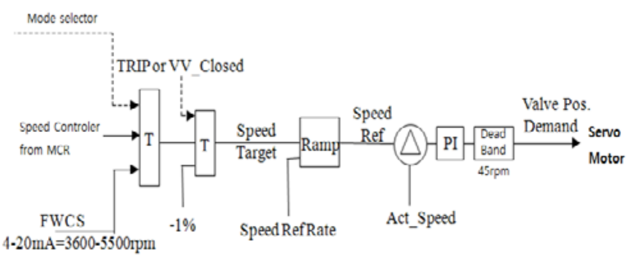

Figure 1. Concept of the MFWP speed control

2.2 Status and Causes

The MFWP speed of Hanbit units #3, 4 is irregularly fluctuated during normal operation period, although the speed demand signal is not fluctuated. Mechanical wear of the MFWP occurs as the MFWP control valve is frequently operated. Fig. 2 is the graph of the MFWP speed during a normal operation period.

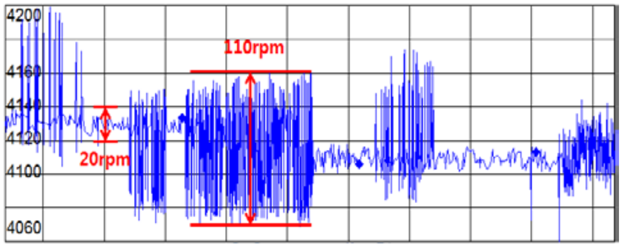

Figure 2. Graph of the MFWP speed in hanbit units 3 and 4

As shown in Fig. 3, the comparative analysis of the MFWP speed demand signal and actual speed signal shows that when the speed deviation is out of the dead band, the MFWP speed is dramatically fluctuated. This happens because the dead band is simply set too high without reducing the speed demand signal hunting. Therefore, it is necessary to apply the delay function for reducing the speed demand signal hunting and adjust the dead band to be low.

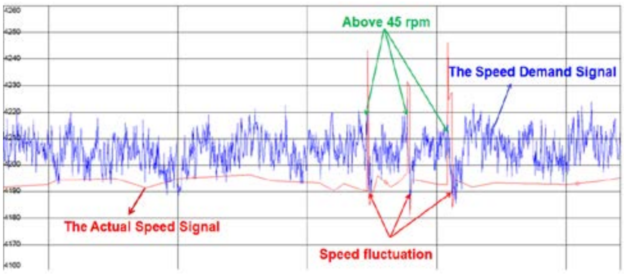

Figure 3. Comparative analysis of the two signals

2.3 Methods and Improvements

2.3.1 Speed Demand Signal Analysis

Fig. 4 is the enlarged graph of the speed demand signal. As shown in Fig. 4, the speed demand signal is changed similarly to the sine function with the amplitude of about 35rpm every 3 seconds periodically.

And the direction of the signal is changed about 12 times similarly to step function during a period. Table 1 shows the analysis of the speed demand signal.

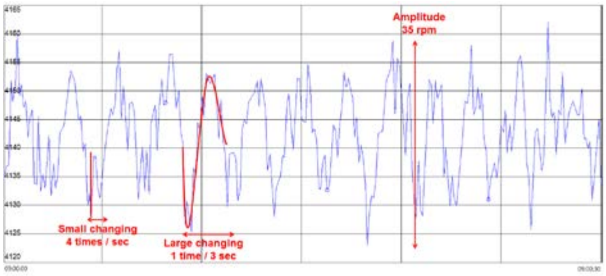

Figure 4. Enlarged graph of the speed demand signal

Table 1. Analysis table of the speed demand signal

	Period	Amplitude	Similar function
Small changing	0.25sec	5~20rmp	Step
Large changing	3sec	30~35rpm	Sine

2.3.2 Selecting the Time Constant of Delay Function and Dead Band

In order to select the time constant of delay function and the dead band, simulations are performed for the sine and step functions which are similar to the speed demand signal.

First, Fig. 5 is the results of the step function simulation. When the step function is entered into the delay function, it takes 1 second to reach approximately 63.2% of the input signal (if the time constant of the delay function is 1 second). So, when the small changing signal with a period of 0.25 seconds and the amplitude of 20rpm is entered, the amplitude of the output signal is reduced to 3rpm.

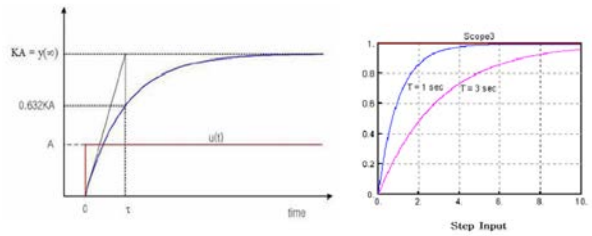

Figure 5. Results of step function simulation

Second, Fig. 6 is the results of the sine function simulation. When the sine function is entered into the delay function, the amplitude of the output signal is reduced to 45% (if the time constant of the delay function is 1 second). So, when the large changing signal with a period of 3 seconds and the amplitude of 35rpm is entered, the amplitude of the output signal is reduced to 16rpm.

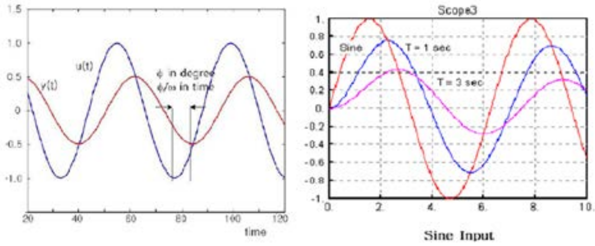

Figure 6. Results of sine function simulation

Therefore, when the delay function with the time constant of 1 second is applied, the amplitude of speed demand signal is reduced to 19rpm. So, the most suitable dead band is the 20rpm which is slightly larger than the maximum amplitude of the speed demand signal.

2.4 Results

As shown in Fig. 7, the actual speed of the MFWP is kept very stable without the fluctuations and the hunting range is reduced to 20rpm after improving the MFWP control methods.

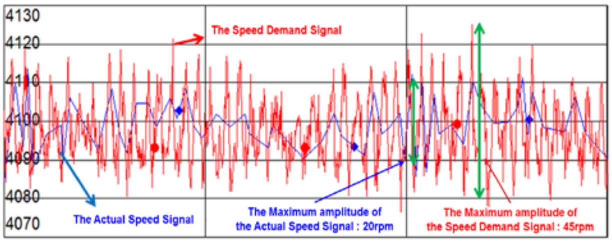

Figure 7. Actual speed signal after improving the MFWP control methods

3. Improvements of the MFWP Control Facility

In this section, we introduce the reliable speed control methods of the MFWP.

3.1 Concept of the Signal Handling Process

The MFWP control facility of Hanbit units 3 and 4 consists of the TMR digital system. Fig. 8 shows the basic signal handling process for the control facility. All of the three signals are input into the three control modules, and the median value among the three input signals is selected for the control. So if two of three signals are failed, the failed signal is selected for control and the MFWP could be tripped or improperly operated.

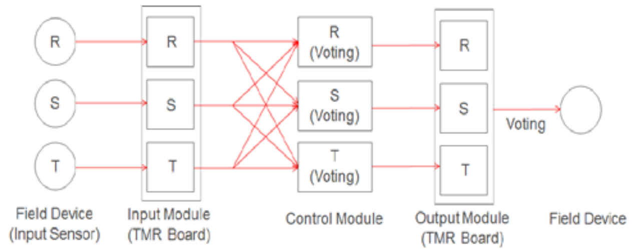

Figure 8. the signal handling process of the Control Facility

3.2 Status

The three speed sensors detecting the speed of the MFWP are located inside the housing of the MFWP. So it is difficult to repair or replace them. Whenever one speed sensor is failed, we must overhaul the MFWP for replacing it due to the concern about additional sensor failure. Therefore, it is required to improve the signal handling process for the reliable operation of the MFWP in the event of two sensors failure.

3.3 Improvements

Since the signal selection methods of the TMR module which is built into the manufacturer's standard couldn't be modified, we have changed the TMR module to the three single modules and added a signal selection logic. Table 2 is the summary of the overall improvements.

Table 2. Summary of the improvements

	Current configuration	Improved configuration
Module	A TMR module	Three single modules
Failed signal distinction	Manufacturer's standard	Above or below the span(4~20mA)
Signal selection methods	Median value	Median value (when no signal failed)
		High value (when 1 signal failed)
		Normal value (when 2 signals failed)

3.4 Results

The MFWP can operate reliably when two speed signals fail after improvements of the signal handling process. Therefore, the operating and maintenance margins of the MFWP have increased further since the one speed sensor failure is tolerated.

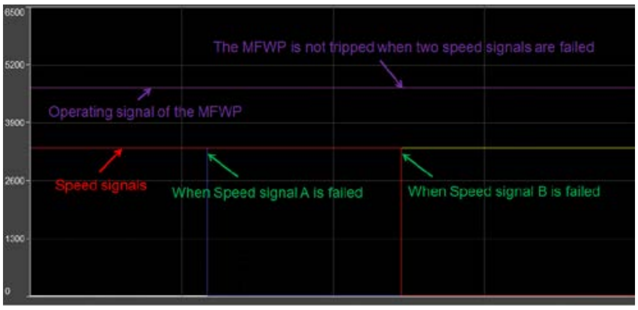

Figure 9. Results after improving the signal handling process

4. Conclusions

This study is conducted to solve a number of problems occurred after replacing the MFWP control facility. First, the actual speed of the MFWP is stabilized by modifying the speed control methods. Secondly, the signal handling process is changed to improve the operating and maintenance margin of the MFWP. Accordingly, the system performance and reliability for the MFWP in Hanbit units 3 and 4 have been improved.

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