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Design of Nuclear Power Plant Online Monitoring System

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1. Introduction

Statistical Quality Control techniques have been applied to many aspects of industrial engineering. An application to nuclear power plant maintenance and control is also presented that can greatly improve plant safety.

As a demonstration of such an approach, a specific system is analyzed: the reactor coolant pumps (RCPs) and the fouling resistance of heat exchanger. This research uses Shewart X-bar, R charts, Cumulative Sum charts (CUSUM), and Sequential Probability Ratio Test (SPRT) to analyze the process for the state of statistical control. And the Control Chart Analyzer (CCA) has been made to support these analyses that can make a decision of error in process. The analysis shows that statistical process control methods can be applied as an early warning system capable of identifying significant equipment problems well in advance of traditional control room alarm indicators. Such a system would provide operators with enough time to respond to possible emergency situations and thus improve plant safety and reliability.

2. Backgrounds

RCP circulates reactor coolant to transfer heat from the reactor to the steam generators. RCP seals are in the pressure part of reactor coolant system, so if it breaks, it can cause small break LOCA. And they are running on high pressure, and high temperature, so they can be easily broken.

Since the reactor coolant pumps operate within the containment building, physical access to the pumps occurs only during refueling outages. Engineers depend on process variables transmitted to the control room and through the station's data historian to assess the pumps' condition during normal operation.

Pump and seal maintenance occurs only during refueling outages carefully planned months in advance. The sooner that maintenance work is scheduled, the more efficient are the planning, procurement, and logistics. The costly reactor coolant pump seals require a lengthy procurement process.

Furthermore, accurate assessment of the pump condition also helps determine whether maintenance deferral is possible. For example, if the reactor coolant pump seals show no signs of degradation, we could use the increased monitoring capability to extend the replacement interval.

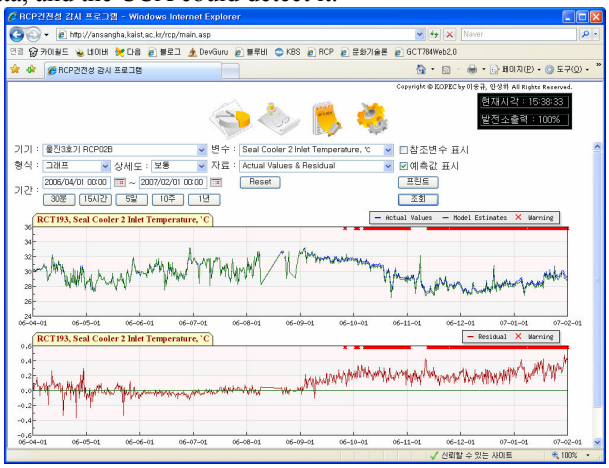
3. Methods and Results

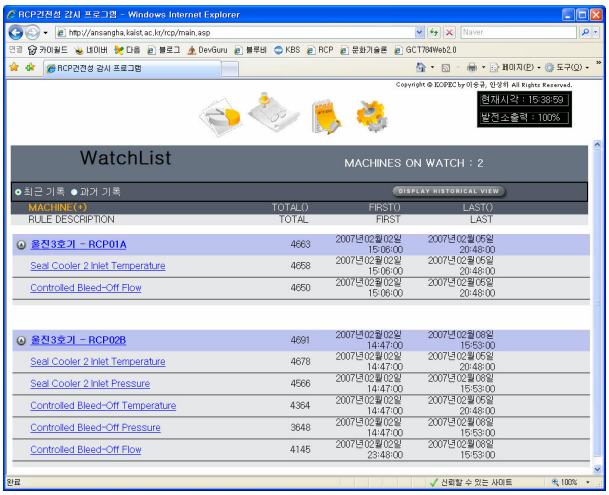
We made an analysis tool named "Control Chart Analyzer" to support validation model. Correlation model makes correlation in normal operation from collected data and validation model uses it for monitoring real operation state. Figure 4-2 shows the flow chart of monitoring system.

The overall structure of monitoring system is shown in Figure 1. Monitoring system consists of Correlation Model and Validation Model. Correlation generator uses IMSL (International Mathematics & Statistics Library) code to make correlation. And Control Chart Analyzer uses Shewart Chart, CUSUM chart, and SPRT for the statistical analysis so far. Control Chart Analyzer is made in Microsoft Visual C++ 6.0 and working in Windows GUI. And I used OpenGL for graphic library. And it is made by the mechanism of axiom design, so we can add any statistical methodology easily.

CCA accepts data through the data manager. Data manager does not accept only real operation data, but data from data generator. After reading data, CCA decides appropriate statistical methodology to analyze data.

As you can see in Figure 1, the residuals from correlation model of NPP Ulchin Unit. 3 in normal operation model could be recognized as the normal state in the CCA. And we made artificial accident from real data, and the CCA could detect it.





3.1 Signal Processing

Sequential analysis is a method of statistical inference whose characteristic feature is that the number of observations required by the procedure is not determined in advance of the experiment. The decision to terminate the experiment depends, at each stage, on the results of the observations previously made. A merit of the sequential method, as applied to testing statistical hypotheses, is that test procedures can be constructed which require, on the average, a substantially smaller number of observations than equally reliable test procedures based on a predetermined number of observations. Each statistical methodology has its own merits and demerits.

4. Conclusion

This study was accomplished to remind the concern about the importance of online monitoring and propose some solutions which are based on academic as well as industrial needs.

Statistical quality control, correlation making tool, and online monitoring tool, and diagnosis are the main topics that are indispensable in order to increase safety, and reliability. There may be a lot of solutions to solve these problems. The online monitoring system is a powerful tool for monitoring the condition of reactor coolant pump seals. Early warning improves scheduling, reduces maintenance expenditures, and delivers exceptional value to nuclear power plants.

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