Pattern Matching Framework to Estimate the Urgency of Off-Normal Situations in NPPs

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1. Introduction

According to power plant operators, it was said that they could quite well recognize off-normal situations from an incipient stage and also anticipate the possibility of upcoming trips in case of skilled operators, even though it is difficult to clarify the cause of the off-normal situation. From the interview, we could assure the feasibility of two assumptions for the diagnosis of off-normal conditions: One is that we can predict whether an accidental shutdown happens or not if we observe the early stage when an off-normal starts to grow. The other is the observation at the early stage can provide the remaining time to a trip as well as the cause of such an off-normal situation.

For this purpose, the development of on-line monitoring systems using various data processing techniques in nuclear power plants (NPPs) has been the subject of increasing attention and becomes important contributor to improve performance and economics. Many of studies have suggested the diagnostic methodologies. [1-4] One of representative methods was to use the distance discrimination as a similarity measure, for example, such as the Euclidean distance. A variety of artificial intelligence techniques such as a neural network have been developed as well. In addition, some of these methodologies were to reduce the data dimensions for more effectively work.

While sharing the same motivation with the previous achievements, this study proposed non-parametric pattern matching techniques to reduce the uncertainty in pursuance of selection of models and modeling processes. This could be characterized by the following two aspects; First, for overcoming considering only a few typical scenarios in the most of the studies, this study is getting the entire sets of off-normal situations which are anticipated in NPPs, which are created by a full-scope simulator. Second, many of the existing researches adopted the process of forming a diagnosis model which is so-called a training technique or a parametric approach. This is the process of fitting the collected data to a pre-set framework. In this study, we proposed the non-parametric approach based pattern matching technique to reduce the uncertainty arising during the selection of models and modeling processes. Preserving the data as collected from off-normal situations, the snapshot data captured in a certain size moving window continues to perform pattern matching with collected data and to determine the most similar case as an off-normal situation. From the database, we are able to provide the remaining time to a trip, in other words, the urgency of off-normal situation.

2. Methods and Results

The proposed methodology can be divided significantly into three types (1) data collection, (2) preprocessing procedures as dimensional compression, (3) pattern matching technique.

2.1 Data Acquisition

While the previous studies have focused on the feasibility of the proposed methodologies, this study aims at field applications. Even though it is practically impossible to collect and verify all possible off-normal cases, it should be very important to increase the reliability of the proposed methodology to obtain as many cases as possible.

We are planning to get the database for off-normal situations using the full-scope simulator installed in the Yeonggwang NPP. This simulator can provide about more than 200 off-normal scenarios. As of August, we have collected ~60 scenarios, and 2 or 3 cases for each scenario were simulated by assuming different initial conditions. In Table 1, several scenarios and their cases are listed for a secondary system.

Table 1: List of scenarios

Content	Initial Condition	Note
SG1 Downcomer pipe rupture	1. 5% Rupture 2. 100% Rupture 3. 50% Rupture	1. Output decreased and stabilization 2. Reactor Stop (After 1minute) 3. Reactor Stop (After 1.5minute)
Water Pump Turbine speed controller malfunction	1. Demand = 0	1. Output increased rapidly
Main steam pipe safety valve malfunction opening stage	1. Severity = 1% 2. Severity = 5%	1. Little or No Change 2. Recognition of opening safety valve
Turbine run-back circuit faults	1. 100%	1. Just Stop

Total 500 variables at each cases are sampled for each second, and the sampling continues during the period the case proceeds to trip or during 5~10 minutes if not a trip case. The collected data are maintained using a spreadsheet program for further investigation.

2.2 Data Preprocessing and Pattern Matching

Figure 1 is showing the concept of pattern matching technique used in this study. As shown in Figure 1, a set of the current signal captured in a moving window is compared with each set of signals in off-normal situation database. The comparison is repeated until the most similar pattern is detected.

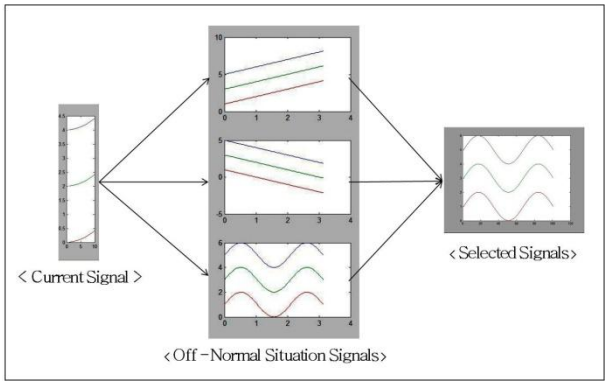

Figure 1: Schematic diagram for estimating off-normal situation using pattern matching technique

In this pattern matching idea, we can calculate the total amount of computational load. If we are successful to get the whole scenarios, the number of data sets is roughly 650 cases (220 scenario × 1~3 cases). Since each case has 500 variables and should be compared the approximately 600 times during maximum 10 minutes if we perform the pattern matching every second. In conclusion, if window size is 10 seconds, the computational load is equivalent to at least $650 \times 500 \times 600 \times 10 = 1.95 \times 10^9$ similarity checks at each second. We need additional computational load to check similarity. Some techniques should be, therefore, applied to compress the dimension.

In this study, PCA (Principal Component Analysis) was used. The application of PCA highly reduces the dimension of the database and allows employing more efficient pattern matching algorithms. The optimal number of principal components is still being analyzed since the upcoming scenarios can affect the decision of the principal components.

2.3 Similarity Measures for Pattern Matching

The signal in the moving window and off-normal scenario database are compared in order to find the best fitted signal by pattern matching technique employing a similarity measure. In this study, we proposed four kinds of similarity measures and each measure's attribute can be summarized as Table 2.

Table 2: Characteristics of similarity measures

Similarity Measure	Property
Absolute value difference	Comparison between the sum of the absolute value of each data's difference, select the smallest interval
Euclidean distance	Comparison of the squared difference between each data value is added by selecting the smallest interval
Mahalanobis	Useful comparison between property values of different range included different relationship
Cosine similarity	Most common measure for document similarity - If similarity is 1, complete accordance, If similarity is 0, complete discordance

Each similarity measure has its own individual feature, so all kinds will be adopted and the method to integrally finalize the results of four measures diagnose will be developed in future.

3. Conclusions

In order to reduce the cognitive load and to increase the available time of the operator for keeping the plant in a safe condition, the awareness of off-normal situations should be of great use to operators. This paper focused on the notification for the perceived urgency of the off-normal situations. The results of this research are expected to enhance reactor safety and economics.

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REFERENCES

[1] L.H. Tsoukalas, R. E. Uhrig, "Fuzzy and Neural Approaches in Engineering," John Wiley & Sons, Inc., 1998.

[2] D. Roverso, "A Neural Model for Event Identification in Dynamic Processes," In: Report HWR-516, OECD Halden Reactor Project, Institutt for Energiteknikk, Norway, 2000.

[3] M.G. Na, S.H. Shin, S.M. Lee, D.W. Jung, S.P. Kim, J.H. Jeong, B.C. Lee, "Prediction of Major Unusual Conditions and Unusual Scenarios for Severe Accidents of Nuclear Power Plants Nuclear Science," IEEE Transactions on, 51, pp. 313 – 321, April. 2004.

[4] K. Hadad, M. Mortazavi, M. Mastali, A.A. Safavi, "Enhanced Neural Network Based Fault Detection of a VVER Nuclear Power Plant With the Aid of Principal Component Analysis," IEEE Transactions on Nuclear Science, 55, pp. 3611 – 3619, Dec. 2008.