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Original Article

Transient Diagnosis and Prognosis for Secondary System in Nuclear Power Plants

Sangjun Park [a], *Jinkyun Park* [b], *and Gyunyoung Heo* [c,*]

[a] *IInstrumentation and Control/Human Factors Research Division, Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, 34057, South Korea*

[b] *Integrated Safety Assessment Division, Korea Atomic Energy Research Institute, 989-111, Daedeok-daero, Yuseong-gu, Daejeon, 34057, South Korea*

[c] *Department of Nuclear Engineering, Kyung Hee University, Yongin-si, Gyeonggi-do, 17104, South Korea*

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ABSTRACT

This paper introduces the development of a transient monitoring system to detect the early stage of a transient, to identify the type of the transient scenario, and to inform an operator with the remaining time to turbine trip when there is no operator's relevant control. This study focused on the transients originating from a secondary system in nuclear power plants (NPPs), because the secondary system was recognized to be a more dominant factor to make unplanned turbine-generator trips which can ultimately result in reactor trips. In order to make the proposed methodology practical forward, all the transient scenarios registered in a simulator of a 1,000 MWe pressurized water reactor were archived in the transient pattern database. The transient patterns show plant behavior until turbine-generator trip when there is no operator's intervention. Meanwhile, the operating data periodically captured from a plant computer is compared with an individual transient pattern in the database and a highly matched section among the transient patterns enables isolation of the type of transient and prediction of the expected remaining time to trip. The transient pattern database consists of hundreds of variables, so it is difficult to speedily compare patterns and to draw a conclusion in a timely manner. The transient pattern database and the operating data are, therefore, converted into a smaller dimension using the principal component analysis (PCA). This paper describes the process of constructing the transient pattern database, dealing with principal components, and optimizing similarity measures.

1. Introduction

Nuclear power plants (NPPs) are increasing the capacity and progressing with much more reliable systems for safety. However, an operator's role should never be underestimated, since the most significant cause of unexpected shutdowns is still human error. Many human errors are induced by an operator's inability to diagnose the transient pattern at its

* *Corresponding author.*
E-mail address: gheo@khu.ac.kr (G. Heo).

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initiation [1,2]. Human errors can be reduced by training with qualified procedures, but these may be graded depending on variation in individuals. Information technology can compensate this differentiation, and it is expected ultimately to improve safety and availability of NPPs [3]. Through interviews, most of the operators could not recognize well what type of transient occurred after a transient state, but they recognized an abnormal state. Therefore, this study started from the following hypothesis: it is possible that operators take proper action to cope with transients at an initial state by recognizing what the transient scenario is and how much time remains until reactor or turbine trip. Consequentially, this is effective for increasing the time to cope with the transient state because operators can reduce the time to diagnosis. The proposed idea is to collect the transient pattern database from a plant simulator and to compare a plant state with the transient pattern database using a pattern matching algorithm [4,5]. The transients in this study were focused on those from the secondary system in NPPs. According to statistics, many unexpected shutdowns result from the secondary system rather than the primary system due to the complexity in terms of operation and maintenance [6]. That is, inspection and maintenance activities are more prone to result in human errors [7,8]. Investigations on trip causes from the secondary system have not progressed because safety of the secondary system is relatively less valued than that of the primary system. This paper will explain the three steps: (1) construction of the transient pattern database; (2) signal preprocessing including the dimension compression; and (3) pattern matching methodology and its verification.

2. Materials and methods

In this study, a pattern searching methodology is developed to decide whether a current plant is progressing to a turbine and/or generator trip and it is based on the database acquired at transient states from a simulator. We hypothesized that an early detection and diagnosis for transients would be possible by extracting the characteristic features from the prior patterns. Also, it is expected that the operators are able to get sufficient time for taking actions through the information regarding the remaining time to trip. As a result, the purpose of this study is that those operators properly cope with transients occurring at a secondary system in an NPP by providing the type of transient and remaining time to reactor or turbine trip through the pattern matching technique.

2.1. *Overall framework*

As Fig. 1 shows a whole framework of this study, the purpose of the transient monitoring system is to indicate the remaining time to a turbine trip, and the possibility of the turbine trip is evaluated by comparing with a set of on-line signals and the transient pattern database in a certain time window. The transient database representing the latent abnormal scenarios which occur due to a malfunction in the secondary system is composed by acquiring signals from the simulation of the NPPs. The acquired data go through several steps. One of the most important preprocessing steps is the dimension compression. The reason for the dimension compression is to minimize the time while performing the pattern matching algorithm [9–12]. Consequently, several hundred variables are reduced in size without losing much information therein. This study performs principal component analysis (PCA) for the dimension compression [13]. Operating data is acquired through a real-time database or data collection system (DCS). The dimension of the operating data is suppressed by the PCA as well. After then, the pattern matching system will start to search the most similar pattern among the stored patterns in the transient database with the operating data. One important factor in this process is to utilize the reasonable similarity measurements. In this study, the feasibility of various similarity measures for the pattern matching was verified and a cosine measure was finally selected. When a certain pattern is detected and interpreted as the departure of a transient

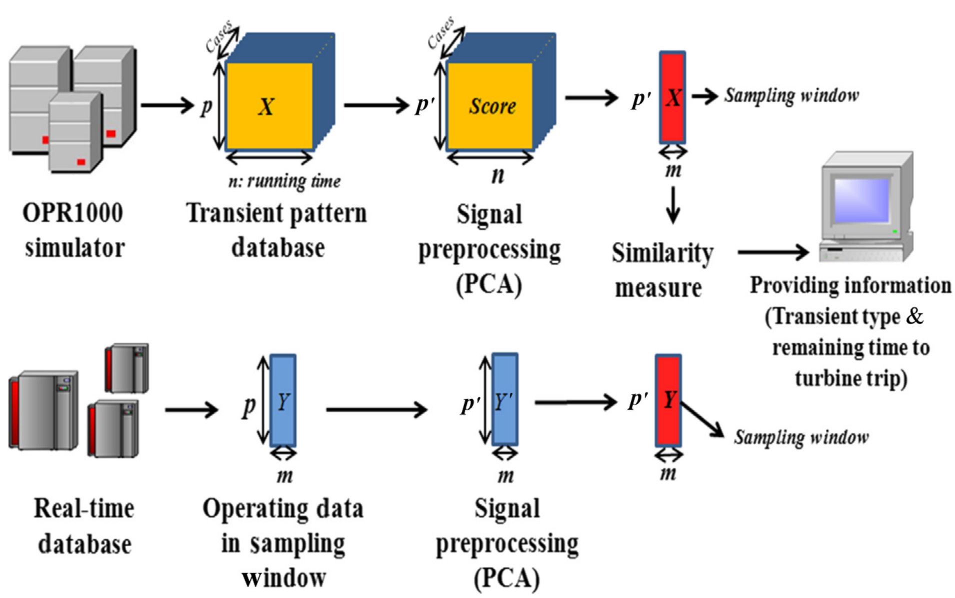

Fig. 1 – Framework of transient monitoring system. PCA = principal component analysis.

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