# Development of an Integrated Early Diagnosis Prototype for NPPs

Kwae Hwan Yoo[a], Man Gyun Na [a*], Hyeon Min Kim [b], Sup Hur [b]
*[a]Department of Nuclear Engineering, Chosun University, 309 Pilmun-daero, Dong-gu, Gwangju, Korea*
**Corresponding author: magyna@chosun.ac.kr*
*[b]Korea Atomic Energy Research Institute, 111 Daedeok-daero, 989 Beon-gil, Yuseoung-gu, Daejeon, Republic of Korea*
*(Corresponding author: magyna@chosun.ac.kr)*

## 1. Introduction

Recently, human errors have very rarely (although it is not often) occurred during the power generation of nuclear power plants (NPPs). For this reason, many countries are conducting researches on the operator support systems of NPPs. Operator support systems can help decision-making of operators in severe accident occurrence [1]. In this study, an operator support system was developed to predict the core uncovery time, reactor vessel failure time, containment failure time, and so forth. Through this system, operator can predict the accident scenario, accident location and accident information in advance. Also, it is possible to decide the integrity of the instrument and predict the life of the instrument. The data was obtained by simulating severe accident scenarios for the Optimized Power Reactor 1000(OPR1000) using the modular accident analysis program MAAP code [2]. The prediction of the accident scenario, accident location and accident information are conducted using artificial intelligence methods.

## 2. Integrated early diagnosis prototype modules

The integrated early diagnosis prototype consists of five modules as subsystem. Table I shows the MAAP code parameter used for the integrated early diagnosis prototype modules.

Table I: MAAP code parameter

| No. | Parameter name |
|---|---|
| 1 | pressure in cavity |
| 2 | temperature of gas in cavity |
| 3 | initial temperature of the water in containment node |
| 4 | mass of water in the containment sump node |
| 5 | core exit temperature |
| 6 | pressure in pressurizer |
| 7 | boiled-up water level from bottom of RPV |
| … | … |
| 78 | collapsed water level in primary system |
| 79 | water level in refueling water storage tank |

Fig. 1 shows the overview of an operator support system. Fig. 2 shows the information and accident diagnosis. It is expected that the operator support system can contribute to improving the safety of the NPP by predicting the accident scenario.

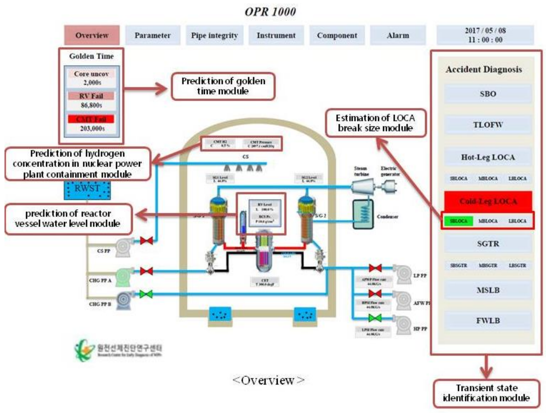


Fig. 1. Overview

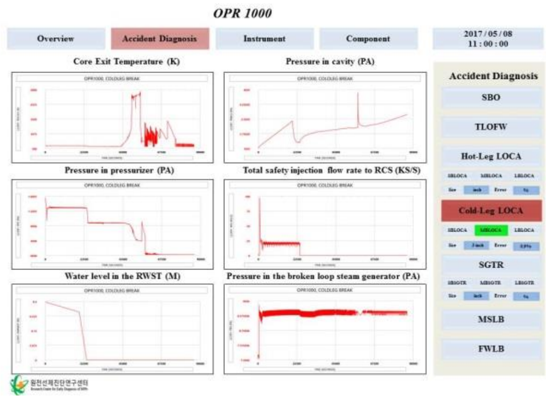


Fig. 2. Information and accident diagnosis.

### *2.1 Transient state identification module*

In this module, the base scenarios are classified by seven initiating events. The base scenarios of seven events have been calculated for OPR-1000 plant : Hot-leg loss of coolant accident (LOCA), cold-leg LOCA, steam generator tube rupture accident, station blackout accident, main steam line break accident, feed water line break accident, total loss of feed water accident [2]. We used three support vector classification (SVC) modules for seven initial event categories. Fig. 3 shows the accident identification method using the trained SVC model. The seven accidents in NPPs are classified using the three SVC modules. The SVC model are trained to classify the transients as shown in table II.

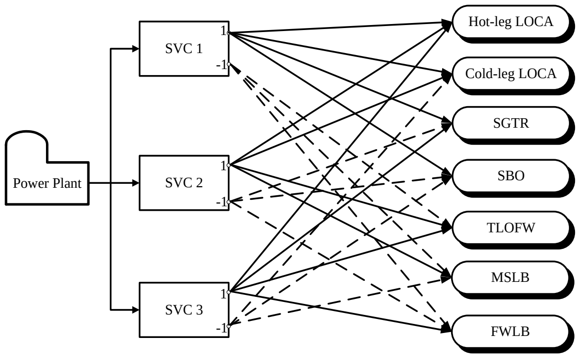


Fig. 3. Accident identification method using the trained SVC model

Table II: Identification of the transients using the SVC model

| SVC model | Hot-leg LOCA | Cold-leg LOCA | SGTR | SBO | TLOFW | MSLB | FWLB |
|---|---|---|---|---|---|---|---|
| SVC1 | 1 | 1 | 1 | 1 | -1 | -1 | -1 |
| SVC2 | 1 | 1 | -1 | -1 | 1 | 1 | -1 |
| SVC3 | 1 | -1 | 1 | -1 | 1 | -1 | 1 |

*2.2 Estimation module of LOCA break size*

The estimation module of LOCA break size consists of hundreds of accident simulation scenarios according to the LOCA break sizes. In case of a large break (LB) LOCA, the break location can be detected easily due to the noticeable change in pressure indicated by the measuring instrument. However, in case of a small break (SB) LOCA, it is difficult to accurately detect the break location due to a small change in pressure indicated by the measuring instrument. In case of SBLOCA, the complete loss of high-pressure safety injection is classified as a type of accidents with a high probability of occurrence. We used cascaded a support vector regression (CSVR) model for prediction of the LOCA break size [2]. Fig. 4 shows the architecture of the CSVR model.

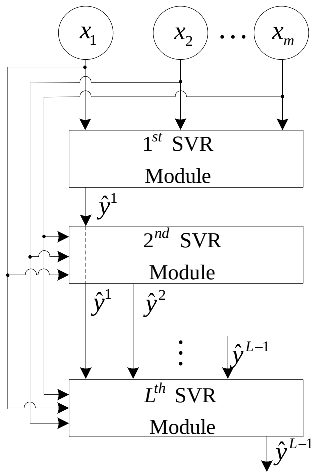


Fig. 4. Architecture of the CSVR model

*2.3 Prediction module of hydrogen concentration in nuclear power plant containment*

The prediction module of hydrogen concentration in nuclear power plant containment was developed to predict hydrogen concentration in nuclear power plant containment in the event of a severe accident. If the NPP operators can predict the hydrogen concentration in the containment under severe accident conditions using this module, the integrity of NPPs will effectively be maintained, and explosions can be prevented [3]. We used a cascaded fuzzy neural network (CFNN) model for prediction of hydrogen concentration in nuclear power plant containment. Fig. 5 shows the architecture of the CFNN model.

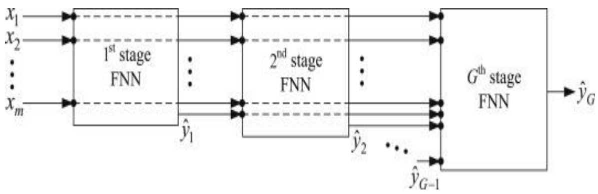


Fig. 5. Cascaded fuzzy neural network (CFNN)

*2.4 prediction module of reactor vessel water level*

The prediction module of reactor vessel water level was developed to estimate the nuclear reactor vessel water level in the event of a severe accident. The CFNN model predicts the nuclear reactor vessel water level according to the elapsed time after reactor shutdown by using the inputs of the predicted LOCA break size and containment pressure [4].

*2.5 Prediction of golden time module*

The prediction module of golden time was developed to predict the golden time for recovering safety injection system (SIS) under a severe accident to prevent core uncover, reactor vessel failure and containment failure. Even if the SIS is not normally operated in the event of LOCA but recovered during the golden time, it may be possible to prevent core uncover, reactor vessel failure and containment failure [5].

## 3. Summary

The integrated early diagnosis prototype is being developed for the purpose of decision-making support for NPP operators during a severe accident situation. If the classification of events and the prediction of critical parameters are available from the integrated early diagnosis prototype, a decision-making will be of help and emergency actions can be very easy [1]. The early diagnosis of accidents and its predictions are useful and important information for NPP operators when they are faced with accidents.

## REFERENCES

[1] S.Y. Park and K.I. Ahn, "SAMEX: A severe accident management support expert," Annals of nuclear energy, Vol. 37, No. 8, pp. 1067-1075, 2010

[2] K.H. Yoo, D.Y. Kim, J.H. Back, M.G. Na, "Prediction of Golden Time Using SVM for Recovering SIS in Severe Post-LOCA Circumstances," presented at INTELLI 2015, St. Julians, Malta, Oct. 11-16, 2015.

[3] G.P. Choi, D.Y. Kim, K.H. Yoo, M.G. Na, "Prediction of hydrogen concentration in nuclear power plant containment under severe accidents using cascaded fuzzy neural networks," Nuclear engineering and design, Vol. 300 pp. 393-402, 2016

[4] D.Y. Kim, K.H. Yoo, M.G. Na, "Reactor Vessel Water Level Estimation During Severe Accidents Using Cascaded Fuzzy Neural Networks," Nuclear engineering and technology, Vol. 48, No, 3, pp. 702-710, 2016

[5] K.H. Yoo, J.H. Back, M.G. Na, "Prediction of golden time using SVR for recovering SIS under severe accidents," Annals of nuclear energy, Vol. 94, pp. 102-108, 2016