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INDENTIFICATION OF COLD-LEG BREAK SIZE IN LOCA ACCIDENT USING ARTIFICIAL NEURAL NETWORKS AND SIMULATION DATABASE

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Contents

- ❑ **Introduction**
- ❑ **The simulation database**
- ❑ **Identification method using ANN-based model**
- ❑ **Results and discussion**
- ❑ **Conclusions**

Introduction

LOCA - Loss Of Coolant Accident

The response of nuclear power plant varies considerably with the size of break

The size of rupture needs to be detected and identified as soon as possible right after reactor scram

ANN

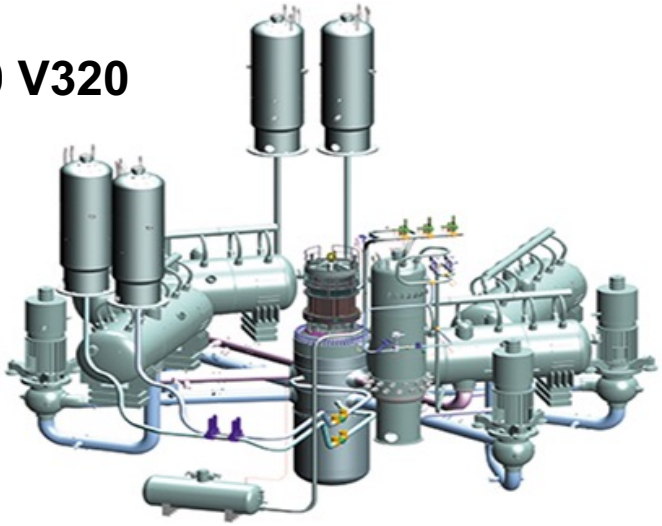
Simulation database

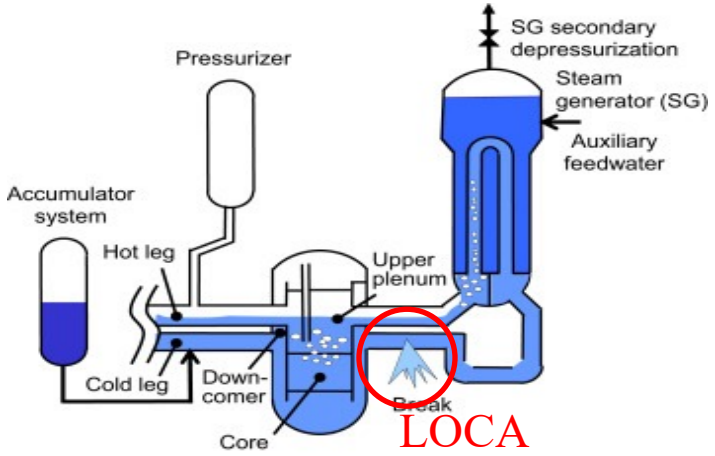
Real database

RELAP5

Database of NPP

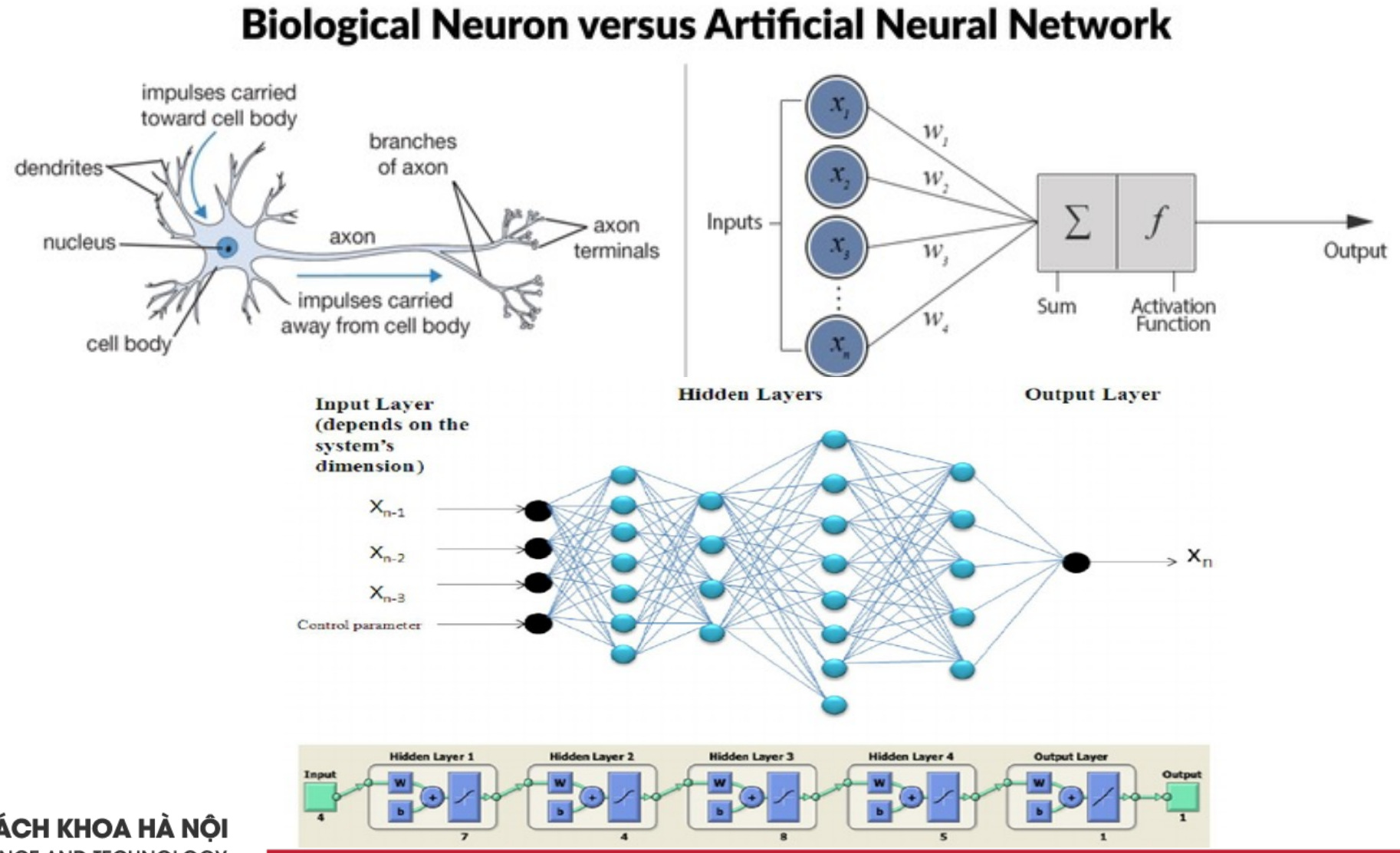
VVER-1000 V320





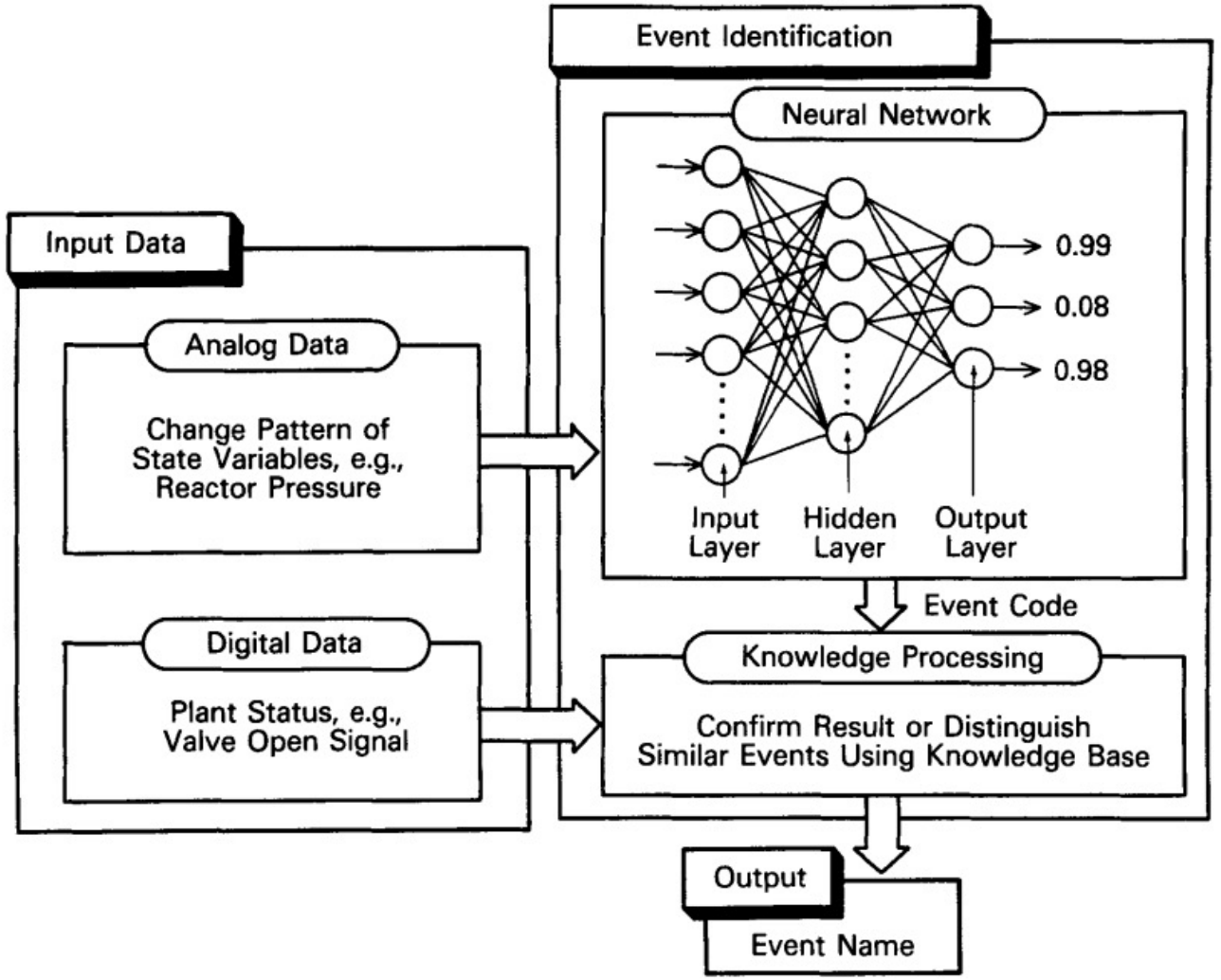
Introduction

❖ *Artificial Neural network - ANN*



Introduction

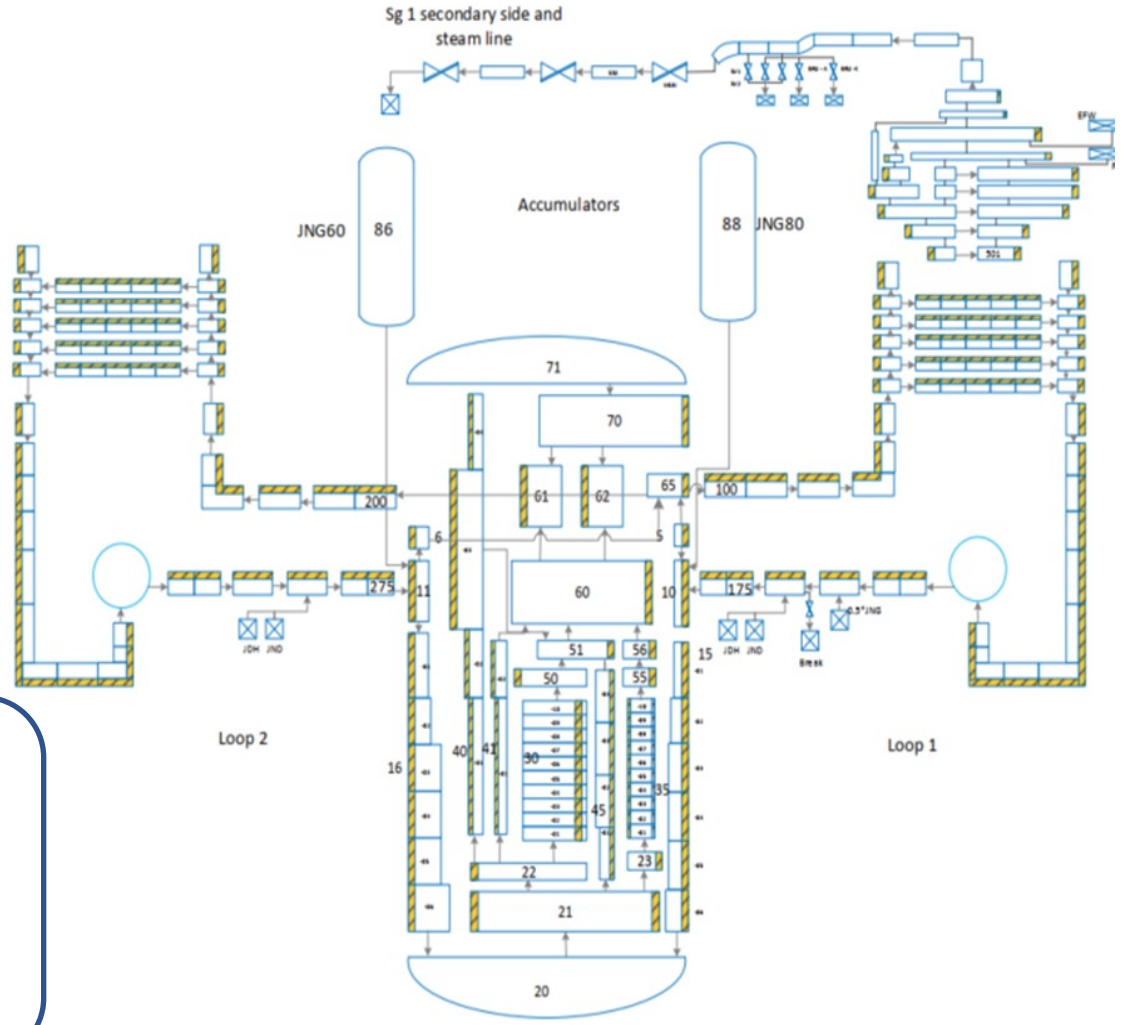
- Transient Identification using ANN (Y. Ohga & H. Seki (1993)



The simulation database

- **Construct the LOCA accident simulation database**
  - ✓ **Small break size (SB-LOCA): 25-100 mm**
  - ✓ **At the cold-leg of the VVER-1000 NPP**
  - ✓ **Time step: 1 s after scram and 3 s before**

RELAP5



- **839 data points corresponding to different cases of 39 break sizes varying from 25mm to 100mm**

The simulation database

❑ Process data obtained from RELAP5

The simulation database:

Normalized

- **Used for analysis, determining parameters that have little or no change over time for different break sizes**

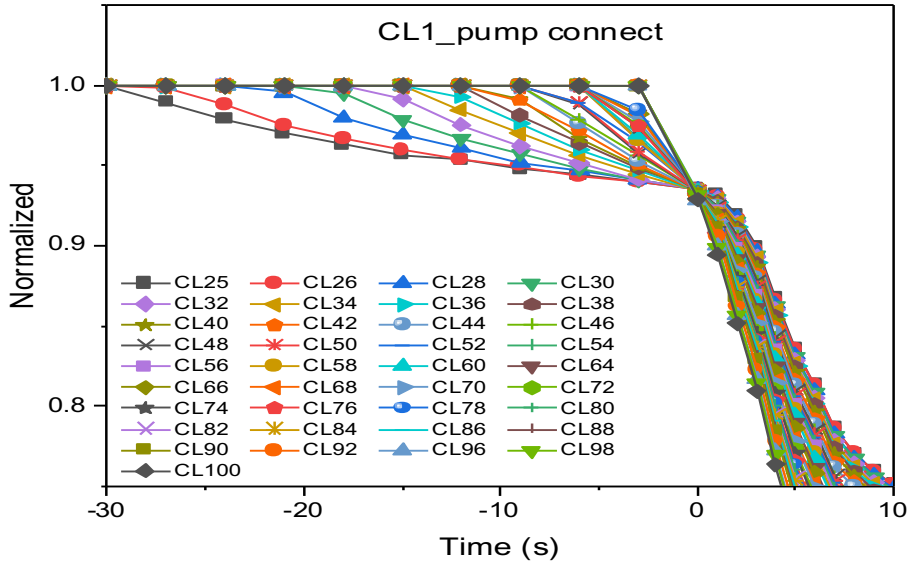
Select key parameters

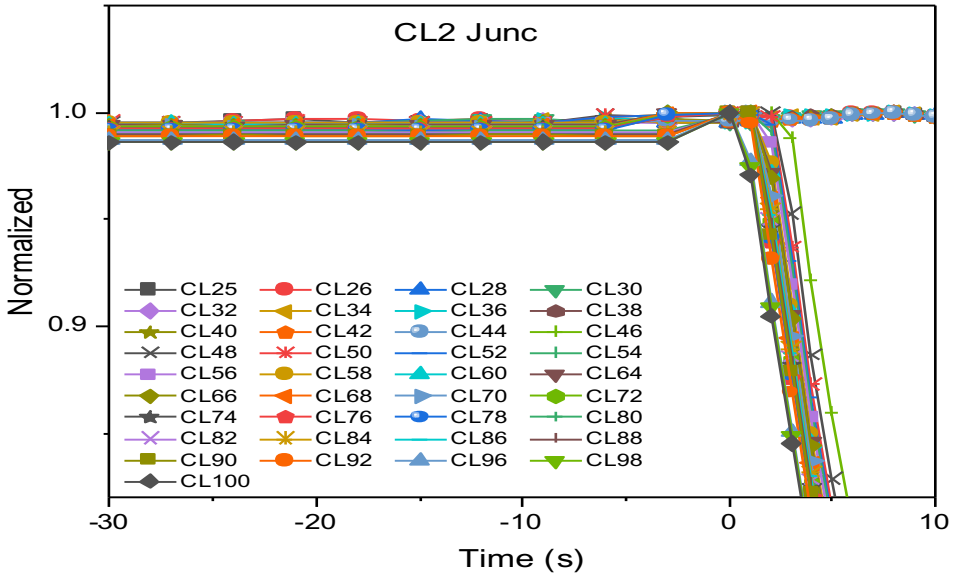
- **That is useful in determining detect the break size**

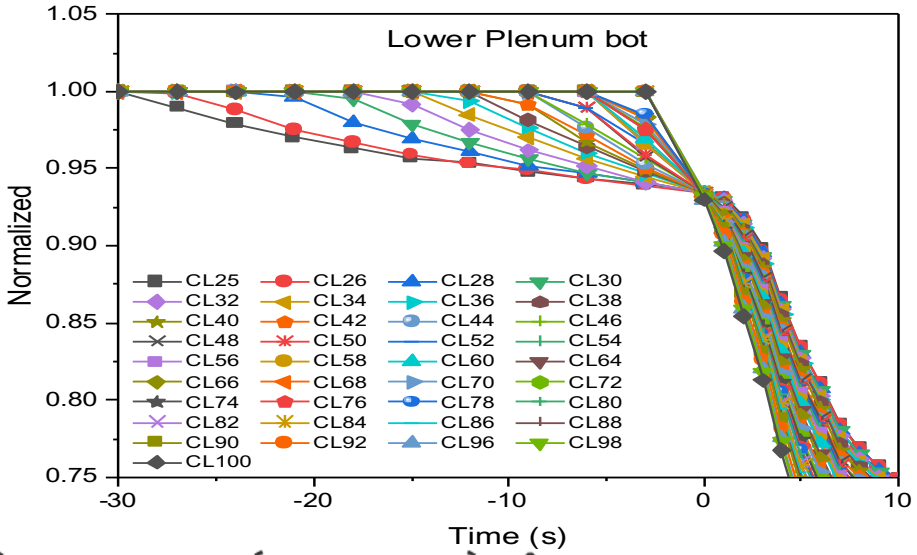
No.	Nomen clature	Name	No.	Nomen clature	Name
1	p	Lower Plenum bot.	7	mflowj	SG-BRU-K valve
2	p	Upper Plenum mid	8	cntrlvar	PRZ Collapsed Level
3	p	SG per Plate-S Dryer	9	cntrlvar	SG-Level
4	mflowj	CL Junction	10	mflowj	HL Junction
5	tempf	Fluid temperature at Hot Leg	11	p	HL-Upper Plenum
6	rktpow	Kinetic Power	12	p	CL-pump connect

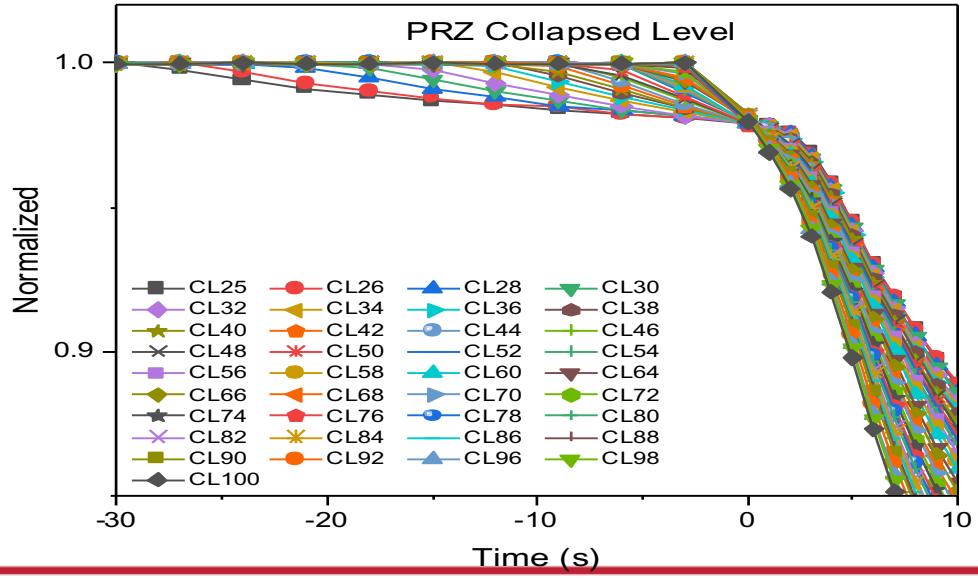
➢ **There are 12 most important key parameters were selected, which were significantly influenced in the evolution of LOCAs**

The simulation database





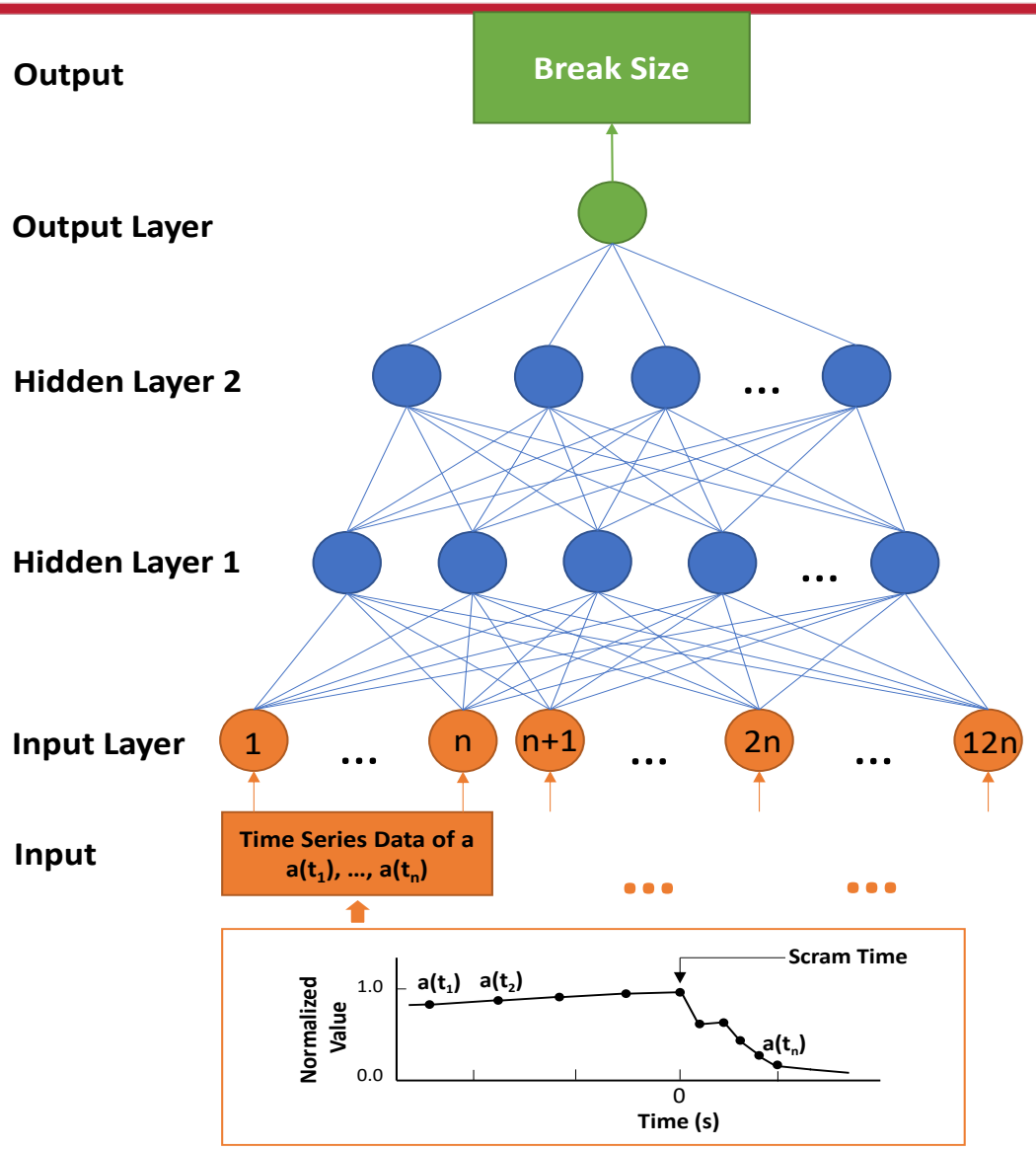




Indentification method using ANN

- ✓ **The type of ANN used is the *multilayer feedforward net***
  - ○ ***1 input layer*: 252 neurons**
  - ○ **2 hidden layers: *Trial-and-Error* method**
  - ○ **1 output layer: 1 neurons**

- ✓ **The transfer function in input and output layer is linear transfer function (*purelin*), while the functions of log-sigmoid (*logsig*)**



Indentification method using ANN

❑ *Trial-and-Error* method

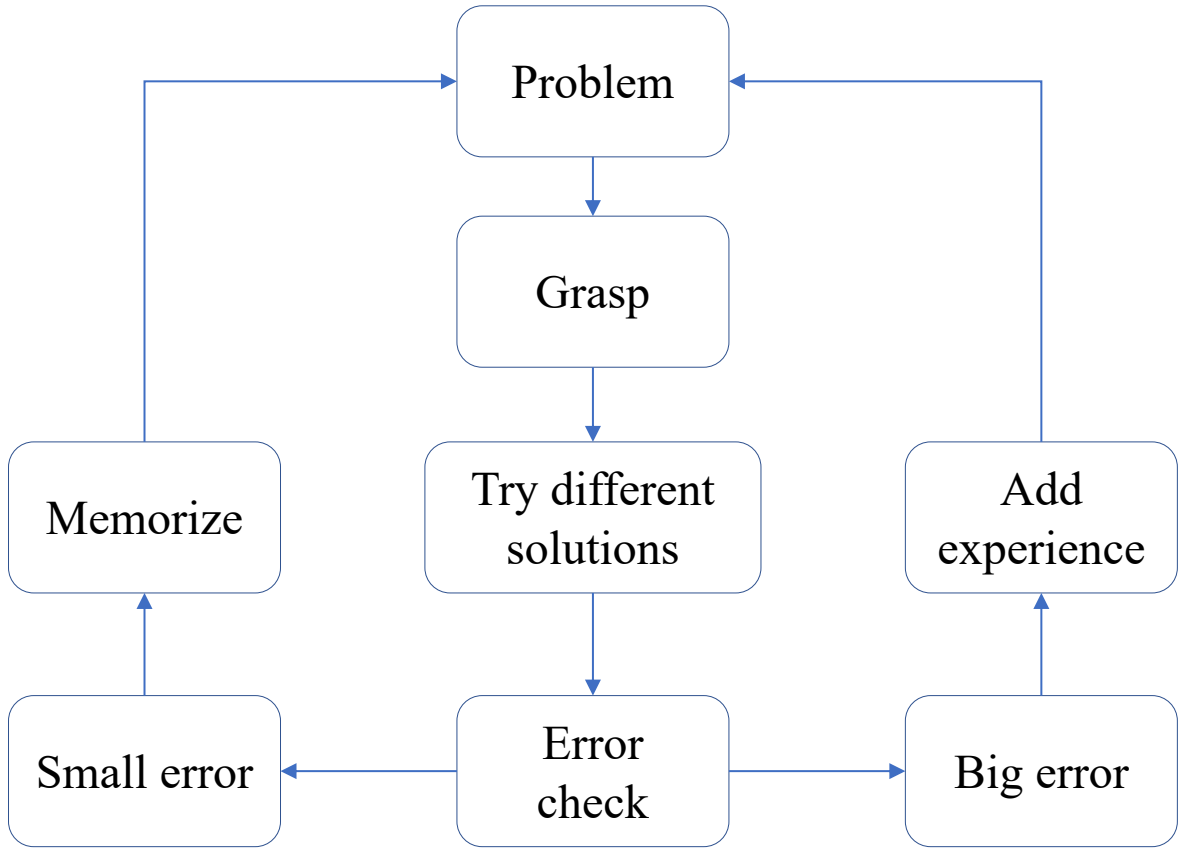
✓ The mean square error:

$$MSE = \frac{\sum_i \left(y_{i,target} - y_{i,pred}\right)^2}{n}$$

✓ The coefficient of determination:

$$R = 1 - \frac{\sum_i \left(y_{i,target} - y_{i,pred}\right)^2}{\sum_i \left(y_{i,target} - y_{mean}\right)^2} \; \epsilon[0,1]$$

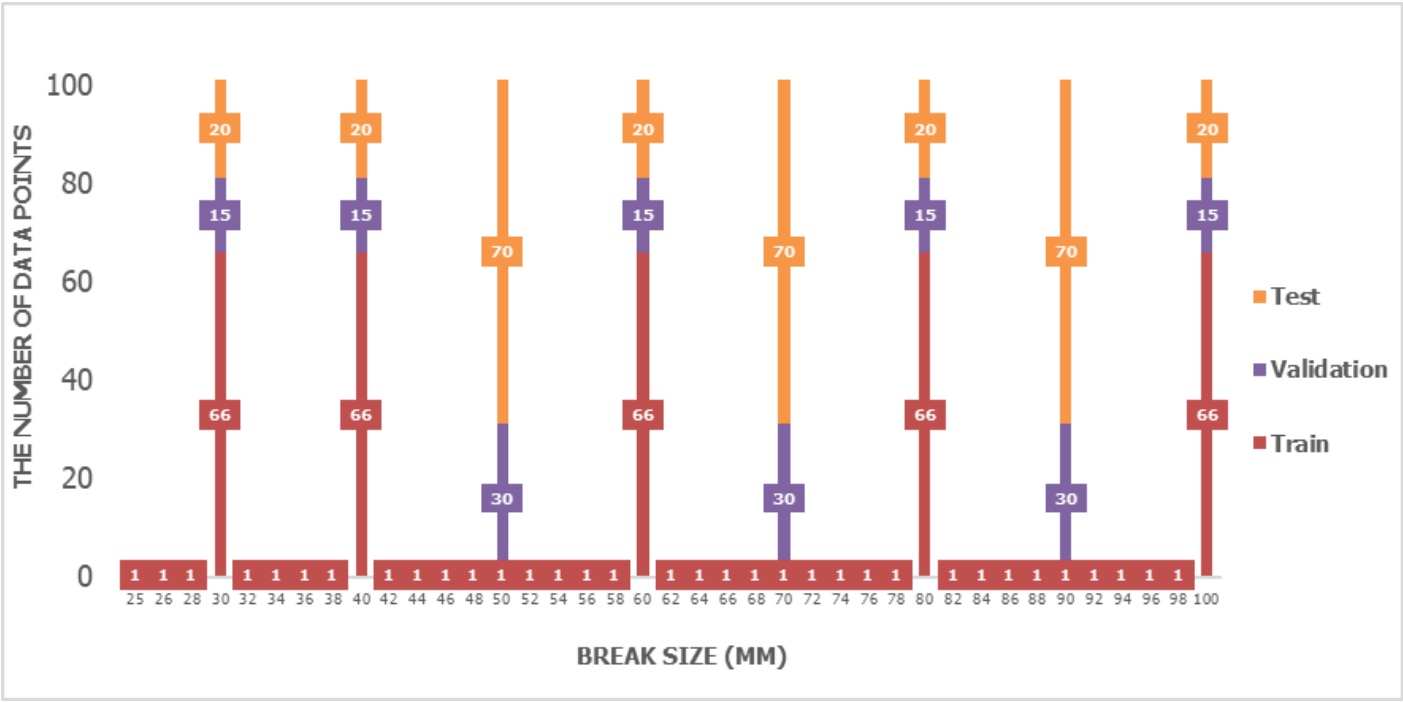
➢ To determine the number of neurons in each hidden layer



Indentification method using ANN

❑ The data division for ANN training

- ✓ With 839 data points is divided into three parts: Training, Testing and Validation.
- ✓ To avoid overfitting, the ANN is trained with the *Levenberg-Marquardt* algorithm along with early stopping.



- ✓ With break sizes of 50, 70, and 90 mm, the training data consists of only one point, the rest of the data corresponding to other uncertainties is divided into test and validation data.

➢ It is possible to check the interpolation and predictive ability of the ANN for uncertain cases.

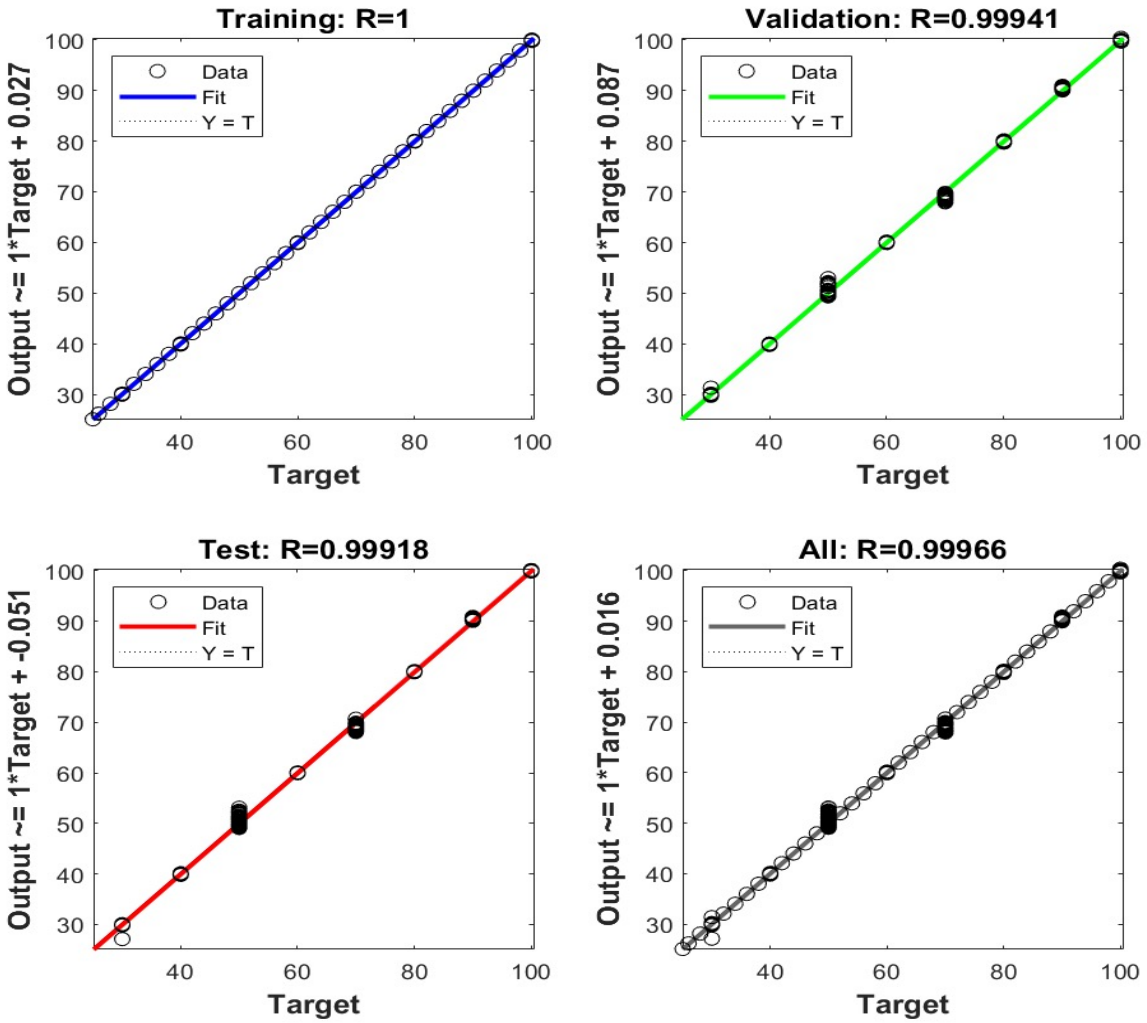
Results and discussion

- ✓ **Each ANN structure is trained 10 times with random initiated weights and biases**
- ✓ **Then the averaged values of training performance (MSE) and coefficient of determination of test data (R) were obtained**
- ➢ **The structure (30-20) is chosen as the optimal structure, because it has the best accuracy at the test data as well as training performance and ANN size are also good.**

Structure of hidden layers	Test data (R)	Performance (MSE)	Total number of weights and biases
10-10	0.96221	1.24E-8	2541
15-15	0.99237	3.89E-9	3886
20-10	0.99485	4.34E-9	5061
20-20	0.99560	7.81E-10	5281
25-25	0.99141	9.84E-9	6726
30-10	0.99278	6.75E-9	7581
30-20	0.99672	2.15E-10	7901
30-30	0.99386	4.89E-10	8221
40-10	0.99424	2.32E-10	10101
40-30	0.99347	8.74E-11	10941
40-40	0.98972	5.93E-11	11361
45-45	0.99065	8.89E-11	13006
50-30	0.99265	5.67E-11	13661

Results and discussion

- ✓ **Most of the data points are in the 1:1 linear regression line, showing good capability to accurately predict by the ANN-based model.**
- ✓ **In the cases where there is no uncertainty in the training data (data points are 50, 70 and 90 mm), the prediction results are slightly biased**
- ➢ **The ANN-based model capable of relatively accurate identification even with uncertainty of input parameters added.**



That Figure shown a comparison of predicted results

Conclusions

1. **This study has performed the construction of SB-LOCA fault simulation data with different break sizes at the cold-leg in a nuclear power plant using VVER-1000 technology.**
2. **With simulated database, the authors have built an ANN-based model to identify the corresponding break size.**
3. **The results showed that the accuracy of the ANN-based model, even when considering the uncertainty of the input data.**
4. **This proves the great potential of the application of ANN in quickly identifying the break size in the LOCA.**

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