Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

A Study on Soft Computing Applications in I&C Systems of Nuclear Power Plant

H. T. Kang, H.Y. Chung
Nuclear Environmental Technology Institute, Korea Hydro & Nuclear Power Co., LTD, nalburushim@khnp.co.kr
P.O. Box 149, Yuseung, Daejeon, 305-600, KOREA

1. Introduction

In the paper, the application of the soft computing based nuclear power plant(NPP) is discussed. Soft computing such as neural network(NN), fuzzy logic controller(FLC), and genetic algorithm(GA) and/or their hybrid will be a new frontier for the development of instrument and control(I&C) systems in NPP. The application includes several fields, for example, the diagnostics of system transient, optimal data selection in NN, and intelligent control etc. Two or more combining structure, hybrid system, is more efficient. The concept of FLC, NN, and GA is presented in Section 2. The applications of soft computing used in NPP are presented in Section 3.

\

2. Concept of FLC, NN, and GA

In data processing, FLC, NN, and GA and/or the hybrid system could be applied efficiently, whose goal is to optimize the data, input and output, mapping, and then to obtain an optimal solutions.

2.1 Fuzzy Logic Controller

The input, as expressed in vectors, is fuzzified, and then the fuzzified variables are processed in the form of if-then rules base, and the result is defuzzified to give a crisp output as an input to the process [1]. FLC make it possible to handle non-linear problems in a straight forward manner. FLC attempts to model the imprecise or vague modes of reasoning that are a part of the human ability to make decisions in an environment of uncertainty.

2.2 Neural Network

Typically, NN has a multiple vector as an input and another multiple or one vector as an output. Input and output connection is carried out by adjusting the weights, in a manner of training by a sample data, in NN until the error between the desired output and actual output is minimized in a least squares [2]. The relationship between the input and output is usually expressed in terms of a weight matrix.

2.3 Genetic Algorithm

GA provides a means of achieving optimal solution or conditions based on the survival of the fittest phenomena observed in evolutionary genetics [3]. GA could be used to select optimal inputs and outputs in both NN and FLC, or can be used in the training of the neural networks. Also, GA can be used in the selection of fuzzy rules.

3. Applications of Soft Computing in NPP

3.1 Fuzzy Logic Control of Nuclear Reactor

A FLC could be designed based on the operator's experience. So, the operator can have a relation with rod speed and the difference of power demand and reactor power level. From this view, we can design a FLC to control the power of a nuclear reactor. The mapping of the FLC can be structured, which could be robust, by heuristics.

A rod control system of reactor power is shown as in Figure 1. P_{ref} is compared with NIS power, T_{avg} is compared with $T_{ref.}$ The summation of the two inputs is total error.

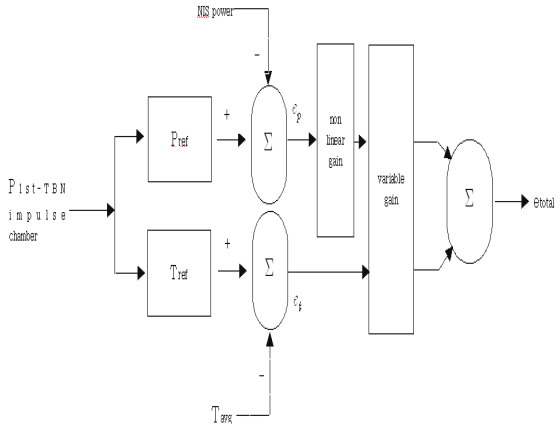

Figure 1. A rod control system of reactor power

To fuzzify the system, two input variables and one output are needed. One input is $e_{p,}$ another is $e_{t.}$ Output is rod speed, $R_{s.}$ Figure. 2 shows the structure of the closed-loop system with FLC, where P_{ref} is power demand, T_{ref} is reactor reference temperature, R_p is the NIS power, R_s is the rod speed, and $e_{p,}$ e_t are the error calculated respectively

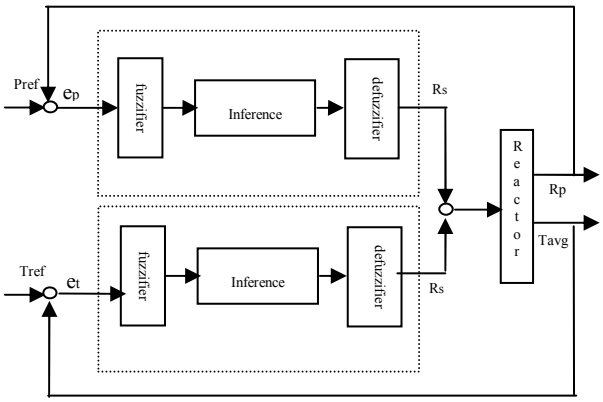

Figure 2. Structure of the closed-loop system with fuzzy logic controller.

e_p, e_t are bell-shaped membership functions, being converted into three linguistic terms, negative(N), zero(Z), and positive(P), as shown in Figure 3.

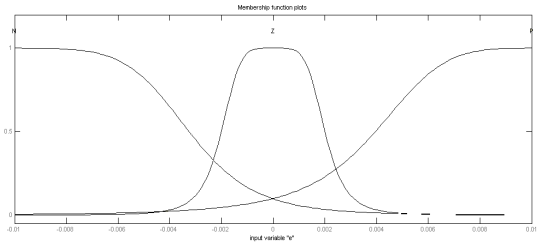

Figure 3. Error membership functions.

Rod speed, R_s, is triangular-shaped functions, being converted into three linguistic terms, negative(N), zero(Z), and positive(P), as shown in Figure 4.

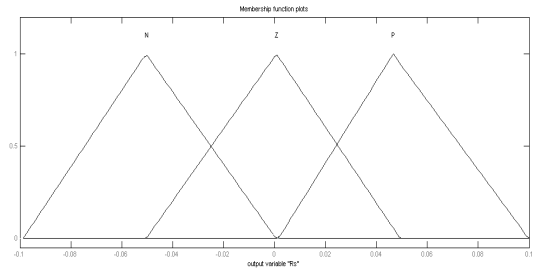

Figure 4. Rod speed membership functions.

Fuzzy if-then rule bases used to control the power of the reactor, temperature of the reactor are shown as in Table 1 and 2, respectively. As shown table 1, 2, two rules are synthesized into one rule. We can feed the synthesized output to controlled system.

Table 1. A simple fuzzy if-then rule 1

e_p	R_s
N	N
Z	Z
P	P

Table 2. A simple fuzzy if-then rule 2

e_t	R_s
N	N
Z	Z
P	P

The overall mapping of the FLC is shown in Figure 5. The FLC mapping implies the FLC has a characteristic of a proportional controller.

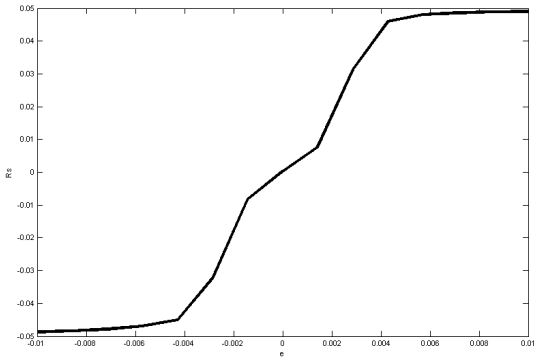

Figure 5. FLC mapping

The mapping obtained can be widely applicable in nonlinear techniques. The controller is verified using 1-point reactor dynamics.

4. Conclusion

The use of soft computing, such as NN, FLC, and GA individually and in a hybrid structured has been demonstrated in the field of I&C system in NPP. Until now, very few of technologies have been implemented in NPP. The soft computing, however, will be clearly efficient compared with the conventional methodologies. Computational intelligence will be used a means for assistance to the nuclear engineering. With the efforts to the improvement of physical simulation, soft computing can be useful to assist NPP design and operation.

REFERENCES

[1] C.C.LEE, Fuzzy Logic in Control Systems: Fuzzy Logic Controller – Part 1,IEEE Transactions on Systems, Man, and Cybernetics, Vol., 20, no 2, March/April,1990.

[2] Bernard Widrow, Michael A. Lehr, 30 Years of Adaptive Neural Networks:Perceptron, Madaline, and BackPropagation, Proceedings of the IEEE, Vol. 78, No. 9, September 1990.

[3] David E. Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley, 1989.

[4] Gurdal Arslan, Kwang Y. Lee, Stability Analysis of a Fuzzy Logic Controller, Proceedings of the American Control Conference Albuquerque, New Mexico, June 1997.