# Application of artificial intelligence techniques in modeling and control of a nuclear power plant pressurizer system

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## Introduction

In pressurized water reactor (PWR) nuclear power plants (NPPs) pressure control in the primary loops is fundamental for keeping the reactor in a safety condition and improve the generation process efficiency. The main component responsible for this task is the pressurizer. The pressurizer pressure control system (PPCS) utilizes heaters and spray valves to maintain the pressure within an operating band during steady state conditions, and limits the pressure changes during transient conditions. Various protective reactor trips are generated if the system parameters exceed safe bounds. Historically, a conventional proportional-integral-derivative (PID) controller is used in PWRs to keep the pressure in the set point, during those operation conditions. The purpose of this work is two-fold: firstly to develop a pressurizer pressure model based on ANNs for a PWR plant; and secondly to develop fuzzy controllers for the ANN model, tuned by GA, and compare their performance with conventional controllers. Data from a 2785 MWth Westinghouse 3-loop PWR LABIHS simulator was used to test both the pressurizer ANN model and the fuzzy controllers.

## Methodologies

Much effort has been used to overcome the difficulties to model nonlinear complex systems such as the nuclear power plants. The NPP are difficult to model, among other factors, due to the parameters dependence on the time-varying power level. The use of ANN in this context is very promising thanks to their ability in performing functional mappings of nonlinear functions. The plant variables used to model the pressurizer by a feedforward neural network with SCG backpropagation training algorithm and 19-13-1 neurons is showed in Fig. 1.

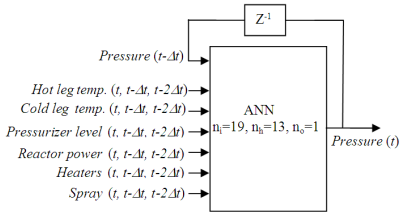


Fig. 1 -. ANN architecture.

Likewise, controlling the NPP systems is difficult due to their complex, time varying and insufficiently known parameters. The application of artificial intelligence techniques as fuzzy logic and genetic algorithms in the control of those systems have been applied recently with good results. The block diagram of the PPCS is presented in the Fig. 2. The pressurizer pressure is the controlled variable and its normal value is 157.08 kg/cm$^2$ – the point where the system is stable with the variable heater on at half capacity, compensating heat losses for ambient.

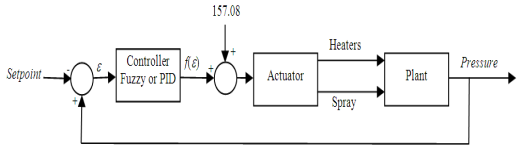


Fig. 2. - Pressurizer control block diagram.

## Results and Discussion

The purpose of this work was satisfactory, since the developed NPP ANN model has achieved similar response to the numeric model for a wide range of transients in the nuclear power of the simulated plant, and the fuzzy controllers presented similar response compared to the conventional controllers, with little advantage to the fuzzy ones, probably due to their intrinsic characteristic to adapt their gain with respect to the error changes. TheTable 1 summarizes the response of the two controllers types (conventional and fuzzy) in terms of the *Integral of Time Multiplied by Absolute Error* (ITAE) for each control strategy implemented: proportional (P), proportional-integral (PI) and proportional-integral-derivative (PID).

Table 1: ITAE obtained for the controllers

| Controller | Conventional | Fuzzy | Error (%) |
|---|---|---|---|
| P | 1856.7 | 1262.8 | 32.0 |
| PI | 460.7 | 405.1 | 12.0 |
| PID | 385.2 | 348.4 | 9.5 |

One may look up more information about this work [1] in Progress in Nuclear Energy, 63 (2013) 71-85.

## References

[1] Oliveira, M.V., Almeida, J.C.S., “Application of artificial intelligence techniques in modeling and control of a nuclear power plant pressurizer system”. Progress in Nuclear Energy, 63 (2013) 71-85.