Performance analysis of PID and Fuzzy Controllers in Process Instrumentation

Brean Richard P[1], R. P. Behera[2]

[1]Sastra University, Department of Instrumentation

[2]Department of EIG, SO/F, IGCAR, Kalpakkam, Thanjavur -613401, Tamil Nadu, India

Abstract: *There are many process controller techniques are in use or being developed to control the changes in industrial parameters. At present the temperature of the liquid sodium (which is a coolant) in the reactor is being maintained using the local heaters on the sodium pipeline. So this project is proposed to change the control function for distributed heater in the sodium pipeline using the PID and Fuzzy logic controller. The performance of both controllers is studied and results are compared.*

Keywords: PID, Fuzzy, Beckhoff hardware, TwinCAT software, Performance.

1. Introduction

A sodium cooled reactor is an advanced type of nuclear reactor in which the liquid sodium is used as a coolant. The liquid sodium is used as coolant because it has higher density than the water (coolant). Liquid sodium removes heat more rapidly and allows much higher power density. Because of its nature of electrical conductivity, it can be moved by electromagnetic pumps. A low neutron absorption coolant is desirable in the reactor, usually the coolant should ideally have low moderation of neutrons and excessive corrosion of materials should be avoided because of coolant.

The liquid sodium is used as a coolant in the reactor for its best properties. The heat from the reactor core is removed by the liquid sodium by making it flow around the reactor core through continuous pipelines. However it ignites spontaneously upon contact with the air (produces aerosols) and also reacts violently with water. So the operation of flow of liquid sodium and maintaining it in a constant temperature becomes more important.

At present the temperature of the sodium pipelines which carry liquid sodium in the reactor is maintained using local heaters which uses ON/OFF control. So this project is proposed to change or develop a control function for the distributed heater using Fuzzy and PID controller. The Fuzzy and PID controller is developed and the performance of both the controllers is compared. This paper is organized as follows: section II describes the process that is taken for analysis, section III describes the PID and Fuzzy controllers used, section IV says the performance with software and hardware.

2. Process Description

For the process the sodium cooled reactor is used, sodium cooled reactor is an advanced type of nuclear reactor in which the liquid sodium is used as a coolant. The liquid sodium is used as coolant because it has higher density than the water (coolant).

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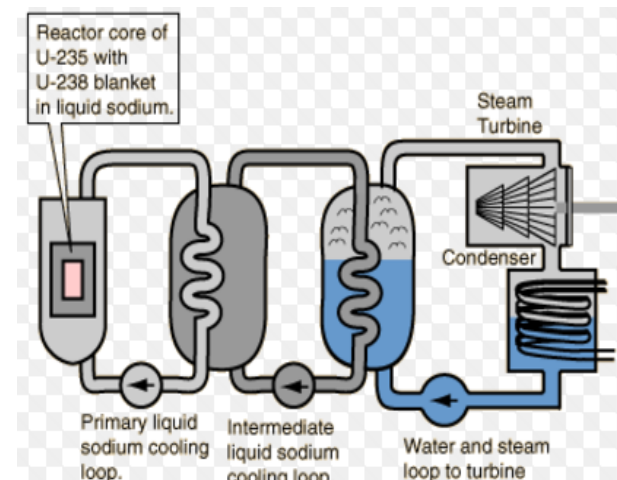The figure 1 below shows the reactor process which is taken into account for analysis.

Figure 1: Reactor using sodium as coolant

Where the liquid sodium, they do not corrode the materials of the nuclear reactor and is suitable to be used as a better coolant because of its best properties.

The high thermal conductivity property of the liquid sodium metal creates a reservoir of heat capacity which indeed provides thermal inertia against overheating. The using of water as a coolant for fast reactor is difficult because water acts as a neutron moderator, which slows down the fast moving neutrons.

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The TwinCAT software which is used to target hardware and changes it into a real-time system, the hardware used here is Beckhoff to create a real-time environment. These two are connected together using a Ethernet cable through a PCI Ethernet chip. The controller developed in Matlab is downloaded to Beckhoff hardware and implemented to thyristor controller and the performance of both controllers is compared.

The data of the reactor is taken and the transfer function is obtained by system identification, the transfer function obtained is used to design PID and Fuzzy controller. Then Beckhoff hardware is connected to the PC and TwinCAT software is used. The controller developed is downloaded to the Beckhoff hardware by integrating the Matlab and TwinCAT software, using TE1410, TE1400 and Windows driver kit and the output of the PID and Fuzzy controller is compared. The results of both the controller is noted.

3. Control Strategy

The TwinCAT software is installed and the connection between TwinCAT and Beckhoff hardware is established, inputs and the outputs has been checked by a simple ladder diagram through Beckhoff. The connection is done using PCI Ethernet card, installed in the mother board in the computer, which enables the connection between hardware and software.

Then the TwinCAT software and Matlab software is interfaced using TE1410 and TE1400 and Windows Driver Kit, which is shortly called WDK, is installed in the computer to enable the interface between them. Then the simulink model created in the Matlab is opened and the corresponding code is generated and saved using the options in the Matlab.

The generated code is then opened in the TwinCAT in C++ options and variables are assigned to each of them, then the corresponding code is downloaded. The TwinCAT is now given the options to generate mappings, and to activate configuration, and now the system is ready to see the outputs, it is then connected to the Thyristor controller through a resistor of 250 ohms, then the controller performance is analyzed.

4. PID Controller

For the better operation proper tuning of a controller becomes essential, which will also improve the product quality, also shortens the down-time and also save money. The process for tuning is really effortless to carry out. Whenever a controller is changed by another, the latest instruments has to be redefined (has to be tuned newly), this can be hard to perform under some circumstances. But various controllers might have parameters for control as digital settings. The three control parameters are as follow: (1) Proportional parameter (2) Integral constant (3) Derivative constant.

The most conventional temperature controllers are three-term PID controllers, in case of analog or microprocessor-based. So the algorithm is purely based on the above mentioned parameters.

5. Fuzzy Logic Controller

Fuzzy controllers are very uncomplicated in use. Three of the stages are involved input, process, output. The membership functions used is triangular, but the form of the membership function used does not matter, instead number of functions added matters. The processing stage is based on a gathering of logic rules in the type of IF-THEN statements which gives heuristic knowledge to the controller through the rule formation by human expert, where the IF part is the first part and the THEN part is called the second part. Consider a simple rule: IF (temperature is "cold") THEN (heater is "high"). Because of the presence of IF-THEN rules, this fuzzy logic controller has a human expert knowledge (Heuristic knowledge).

The development of Fuzzy control system purely depends on expert feeding systems and multivalued logic, it does not require any mathematical representation or derivation like traditional controllers. Instead of getting the derivative controller through mathematical model, fuzzy controller which imports knowledge of controller directly from domain experts (human), who control the real process.

The use of rule formation technique by the human expert in a certain domain makes fuzzy controller very easy to use even for the complex and non-linear systems. In the concept of nuclear power plant, uses conventional model which is totally dangerous, wherein, it is the system which uses rule structure combined with fuzzy theory that makes the implication of fuzzy control possible. In here fuzzy logic controllers for temperature control in the sodium pipeline which carries the liquid sodium coolant.

6. Hardware and Software

In this we will be using Beckhoff hardware and TwinCAT software and the Ethernet cable is used to connect between computer in which the TwinCAT software installed and the Beckhoff hardware. The Windows Control and Automation Technology (TwinCAT) which forms the core of the control system. This software roughly turns any of the PC based system into a real time controller with multiple PLC, NC,

CNC and robotics runtime systems. This software usually converts all the compatible industrial PC into a Real-time controller.

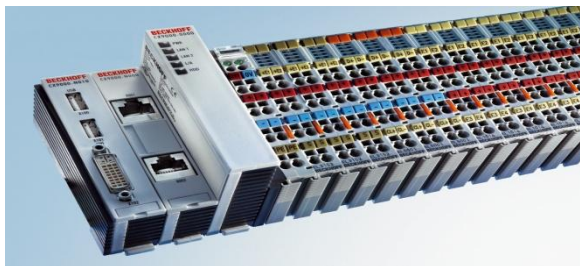Beckhoff Hardware is a simple technology which uses the Master-Slave communication.

Figure 2: Beckhoff hardware

The PID and Fuzzy controller developed, is downloaded to the beckhoff hardware and the output is compared.

7. Simulation Results

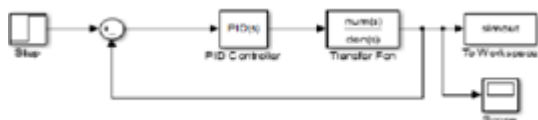The PID controller developed by simulink in MATLAB software is shown in the figure 3 below.

Figure 3: PID controller

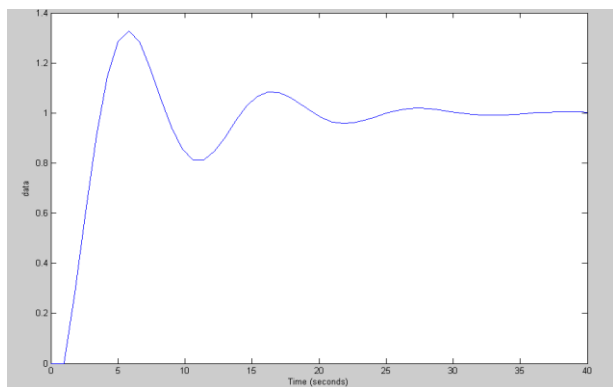The simulation result obtained by the above controller is given by figure 4.

Figure 4: PID controller output

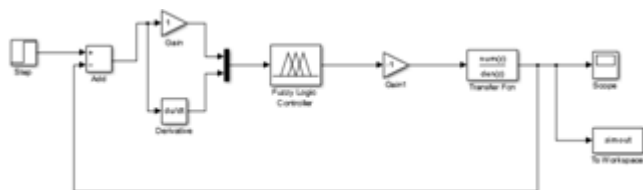Similarly, the simulink diagram for the Fuzzy controller is shown in figure 5.

Figure 5: Fuzzy controller

The output of the Fuzzy controller can be used to analysis the performance and is shown in the figure 6.
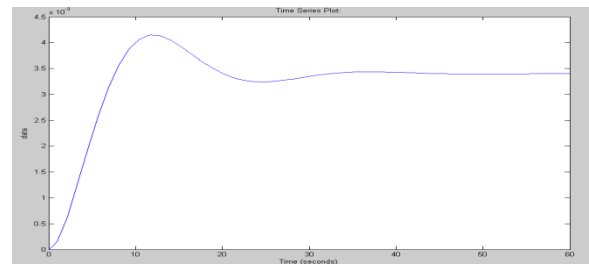

Figure 6: Fuzzy controller output

8. Conclusion

By comparing the output results of PID and Fuzzy controller, we could find that the overshoot and the settling time for the PID controller is higher than that of the Fuzzy logic controller. Thus the use of Fuzzy controller gives good results for the reactor process.

References

[1] Arslan, G. and K. Y. Lee (1997). Stability Analysis of a Fuzzy Logic Controller. Proc. 1997 America Control Conf. 3301-3305.
[2] Driankov, D., H. Hellendoorn and M. Reinfrank (1996). *An Introduction to Fuzzy Control.* Springer, Berlin.
[3] Heger, A. S., N. K. Alang-Rashid and M. Jamshidi, (1995). Application of Fuzzy Logic in Nuclear Reactor Control. Part I: An Assessment of State of-the-Art. *Nuclear Safety.*
[4] Ramaswamy, P., R. M. Edwards, and K. Y. Lee(1993). An Automatic Tuning Method of a Fuzzy Logic Controller for Nuclear Reactors. *IEEE Trans. on Nucl. Sci.*
[5] Zadeh, L. A. (1965). Fuzzy Sets. *Information and Control.*
[6] J. Xu and X.Feng, " Design of Adaptive Fuzzy PID tuner using optimization method, " Proceedings of the 5th World Congress on Intelligent Control and Automation, China, 2004
[7] J. Zhang, N. Wang and S. Wang, "A developed method of tuning PID controllers with fuzzy rules for integrating process," Proceedings of the American Control Conference, Boston, 2004
[8] S.Chopra, R.Mitra and V.Kumar, "Fuzzy controller:Choosing an appropriate & smallest rule set, "International Journal of Computational Cognition, Vol.3, No.4, 2005
[9] S.R.Vaishnav and Z.J.Khan, "Design of PID & Fuzzy logic controller for higher order system," International Conference on Control & Automation (ICCA'07), Hongkong, China, 2007
[10] Design and Simulation of PD, PID and Fuzzy Logic Controller for Industrial Application Ritu Shakya, Kritika Rajanwal, Sanskriti Patel and Smita Dinkar