Analysis and Designing of STF Controller

Himanshu Senger* and Sheo Kumar**

ABSTRACT

The goal of a fuzzy controller is to account for the system's changing properties. It serves the same function as the fuzzy logic controller. To fulfil this purpose, the perfect FLC design is now needed; unfortunately, such a controller has yet to be produced since the fuzzy controller is made up of control rules that are imprecisely designed using traditional controller approaches. The parameters of a fuzzy control system are regularly modified via trial and error. To solve these challenges, we need a mechanism that automatically modifies system settings after analysing fuzzy control response A FLC is a collection of established control rules that are often constructed with the use of expert knowledge. It is common to specify the membership functions of the linked input and output language variables. Several performance measures, including peak overshoot, settling time, rise time, integral absolute error and integral-of-time multiplied absolute error, as well as responses due to step set-point change and load disturbance, are compared between the proposed self-tuning FLCs and their corresponding conventional FLCs. The suggested approach outperforms its conventional equivalent in each case.

Keywords: *DisFLC; STF; Peak Overshoot; Conventional; Fuzzy Rules.*

1.0 Introduction

Fuzzy logic control has become a hot topic in both academia and business. Fuzzy logic controllers have been the subject of much study, both theoretical and practical. Complex control systems have been shown to benefit from the use of fuzzy logic control. When designing a controller, fuzzy logic control is one of the best ways to include qualitative system information into the design. Typically, fuzzy logic control is best suited for poorly mathematically characterised plants that can be controlled qualitatively by skilled operators. Fuzzy logic control methods make it possible to gather and manage human expertise and knowledge while also managing the inherent uncertainty of control processes. There is no theoretical foundation for designing fuzzy logic control, and its performance might be inconsistent due to the operator's experience. This means that although fuzzy logic control systems have made tremendous progress, it is evident that a substantial number of fundamental issues still need to be addressed. Fuzzy control systems rely heavily on stability analysis and systematic design, both of which go hand in hand. These topics have received a lot of attention recently. People's interest in fuzzy control has recently piqued. For example, fuzzy control may be used in cement kilns and heat exchangers as well as in automated railway management systems, vehicle speed controls, and autonomous mobile robot control If-then rules based on conventional control strategy and professional skills are an important part of fuzzy control.

_____

*Corresponding author; Project Planner, Andritz Hydro Pvt Ltd. (E-mail: himanshu.senger@andritz.com)
**Professor, Computer Science & Engineering, CMR Engineering College, Kandlakoya, Telangana, India (E-mail: sheo2008@gmail.com)

It is difficult for linguists to explain their expertise in common English. Control tuning is required for the fuzzy control system in addition to the many variables. The fuzzy expert system approach is used to evaluate the rules in the fuzzy controller under consideration. Extra refers to a function that has been added to the basic fuzzy controller in order to improve its performance. No mention will be made of controllers that are adaptive, self-organizing, or predictive in nature. As a result of analysing any performance stats, our fuzzy controller will not change the scaling constants, fuzzy sets, or fuzzy control rules.

2.0 Fuzzy Logic Controller

In recent years, the fuzzy logic controller has become one of the most popular control systems. If-Then-B statements, which are common in fuzzy logic, are used to describe the controller's operational principles heuristically. A fuzzy logic rule foundation that quantifies an expert's definition of exceptional control. The construction of input and output membership functions is a critical part of the fuzzy logic design process. The basic triangular and trapezoidal forms are used for input and output membership functions. Fuzzy control performance is mostly influenced by the properties of the control rule in most cases, not the forms of membership. adjustment approaches relying on expert knowledge rather than mathematical models need to be examined Human operators, skilled or untrained, will constantly try to manipulate the process input in order to obtain "optimal" process control, whether that means modifying controller gain depending on current process states (usually or). There is no mathematical model that could ever replace the individualised manipulation approach of an operator. This paper describes a system that dynamically adjusts the controller gain based on fuzzy rules and is model-independent and model-simple. Only the controller's gain was evaluated as the output SF is identical to the controller's output. System performance and stability are greatly influenced by the output SF, which has been given considerable consideration. Designing FLCs requires trial and error or training data to fine-tune the input and output scaling factors and other controller settings to ensure optimal performance. SF parameters are the most important of the several factors that may be altered because of their overall impact on how the control functions. It's not clear how important input and output SFs are to the effectiveness of a fuzzy logic control system.

3.0 Self Tunned Fuzzy Logic Controller

Four fundamental building blocks of FLC systems are: fuzzy control rule interface, fuzzy control rule foundation, and inference. We modify the PID's proportional, integral, and derivative contributions during transient and load disturbance periods to achieve a high degree of performance.

If plant dynamics or time delays change, a second layer of self-tuning algorithms may be readily added to the FLC framework. Delay variations affect the FLC gain, hence the FLC gain must be adjusted to compensate. According to the findings, the more the gain or control action, the shorter the time delay. To reduce the amount of control action, lower the FLC gain as the delay rises, and vice versa. By modifying the output membership functions of the first layer of rules based on this connection, it is possible to enhance the fuzzy controller's performance. Consider the following output function for membership with a nominal delay. The control action indicated by the nominal delay provides an output that is too big for the actual system when the nominal delay exceeds the real system time delay. As a result, the controller's gain is effectively increased, and system instability may arise if the difference between the actual delay and the nominal delay becomes too big. The controller gain is inadequate when the real delay is shorter than the nominal delay, resulting in the

system slowing down. Fuzzy control is an interesting alternative to classic control strategies when systems show certain broad operational characteristics without a thorough understanding of the process.

Figure 1: Block Diagram of Self-Tunned Fuzzy Logic Controller
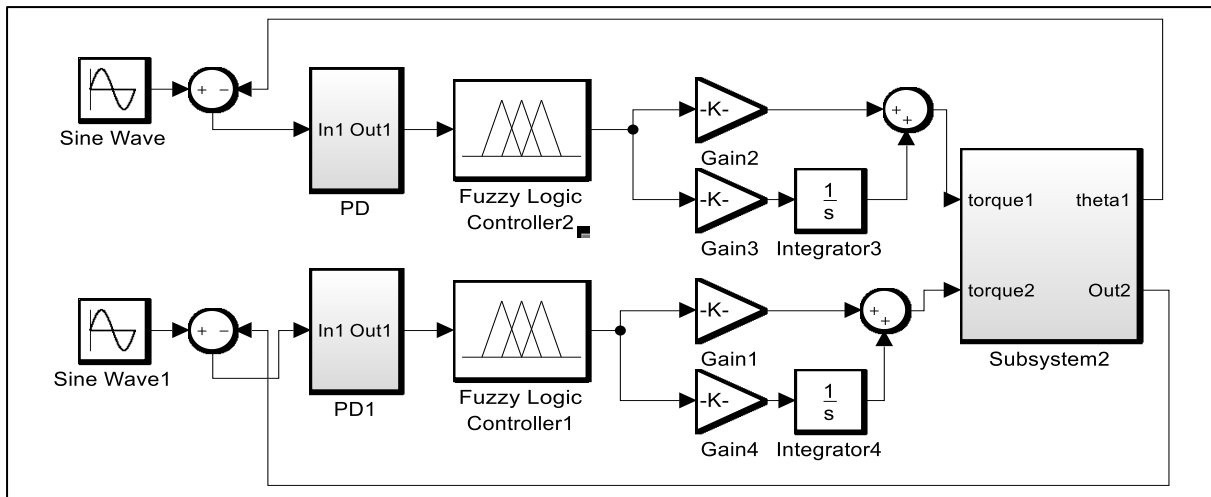
FLUFFY CONTROL is unique in that it can capture the qualitative characteristics of a control system by analysing observable occurrences. Research papers and commercial products from Reliance Electric and Omron both demonstrate the fuzzy control properties. It's remarkable that fuzzy logic can capture system dynamics and implement this notion in real-time for temperature-control systems.

4.0 Results

The below table represents the second order process performance evaluation of the controller and the detailed analysis of two controllers that is manual tuned and self-tuned PID controller a comparative performance is being showcase in the table dead time, gains, fuzzy logic, Integral Absolute Error and Integral total absolute error here we can observe that self-tunning result are more superior in comparison to manual tunning and integral total absolute error outperformed in comparison to integral absolute error.

Table 1: Second Order Process Performance Evaluation-

Dead time	Gains	Fuzzy Logic	IAE	ITAE
0.4	0.03,0.05	PID	5.32	88.23
0.5	0	STFPID	4.89	50.21
0.6	0.03,0.05	PD	6.96	92.59
0.7	0	STPD	5.64	56.98

The same observation was made for a stable system, and the differences in the results from the previous condition are clearly visible. A comparative performance of the controller is shown in the

table dead time, gains, fuzzy logic, integral absolute error, and integral total absolute error. We can see that self-tuning results are superior to manual tuning, and integral total absolute error outperforms integral absolute error.

Table 2: Performance Evaluation for Stable System

Dead Time	Gains	Fuzzy Logic	IAE	ITAE
0.3	0.05,0.05	PID	4.38	66.23
0.5	0	STFPID	2.14	46.99
0.7	0.03,0.03	PD	3.16	68.77
0.9	0	STPD	1.98	32.24

5.0 Conclusion

PID controllers' broad use in industry is projected to continue. Using contemporary control methods to improve its performance and capabilities would be very beneficial. In this piece. We improved the PID controller's performance by using fuzzy logic control. Only the original values of the controller's parameters are utilised for quality control. The suggested control technique requires minimal processing resources to implement. Existing digital PID regulators will continue to function forever. Additionally, the required tuning parameters may be obtained utilising an off-line look-up database. STFL is also effective in plants with a high degree of dynamic fluctuation. Stability properties were evaluated, and a stability safeguard was devised.

References

1. Reddy, G. R., Rayaguru, N. K., Karthikumar, K., Chandrasekar, P., & Murthy, P. S. S. N. (2021, October). Enhancement of Power Quality With Fuzzy Based UPQC in Grid Integrated and Battery Assisted PV System. In *2021 2nd Global Conference for Advancement in Technology (GCAT)* (pp. 1-8). IEEE.

2. Yadav, A. K., Saxena, P., Gaur, P., & Pathak, P. K. (2021). Self-tuning fuzzy PID controller for servo control of hard disk drive with time delay. *International Journal of Information Technology*, *13*(1), 109-114.

3. Saxena, A., Kumar, J., & Agrawal, R. (2021, April). Dynamics and Control Structure for NPID Controller. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1116, No. 1, p. 012141). IOP Publishing.

4. Devan, P. A. M., Hussin, F. A., Ibrahim, R., & Bingi, K. (2021, August). Design and Implementation of Signal Filtering Techniques on Real-time Pressure Process Plant. In *2021 11th IEEE International Conference on Control System, Computing and Engineering (ICCSCE)* (pp. 86-91). IEEE.

5. Zhou, L., Jiang, F., She, J., & Zhang, X. M. (2021). Robust repetitive control for a class of uncertain nonlinear systems. *International Journal of Robust and Nonlinear Control*, *31*(15), 7444-7460.

6.   Saxena, A., Chaturvedi, R., & Kumar, J. (2021). Performance of Two-Link Robotic Manipulator Estimated Through the Implementation of Self-Tuned Fuzzy PID Controller. In *International Conference on Communication, Computing and Electronics Systems* (pp. 721-732). Springer, Singapore.

7.   Romsai, W., Nawikavatan, A., & Puangdownreong, D. (2021). Application of Lévy-flight intensified current search to optimal PID controller design for active suspension system. *International Journal of Innovative Computing, Information and Control*, *17*(2), 483-497.

8.   Sharma, P., Sharma, N., & Parashar, A. K. (2022). Effects of phase-change materials on concrete pavements. Materials Today: Proceedings.

9.   Parashar, A. K., Sharma, P., & Sharma, N. (2022). A study of GGBS based cement concrete with the inclusion of waste foundry sand on mechanical properties. Materials Today: Proceedings.

10.   Mansor, M. A., Othman, M. M., Musirin, I., & Mohammad Noor, S. Z. (2021). Mitigation of power quality issues using UPQC with STF-SRF technique under adverse voltage source condition. *Journal of Electrical and Electronic Systems Research (JEESR)*, *19*, 105-116.

11.   Imchen, S., Srivastava, A., Acharya, D., & Das, D. K. (2021, April). A KKO based PID Stabilizer for Compensation of Low Frequency Oscillations in the Power System. In *2021 5th International Conference on Computing Methodologies and Communication (ICCMC)* (pp. 629-633). IEEE.

12.   Ji, Z., Liu, Y., & Zou, L. (2021). Recent developments on complexity science. *Systems Science & Control Engineering*, *9*(sup2), 1-5.