A Comparative study on SISO and MIMO control techniques

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***Abstract*—This paper exhibits a comparative study between the control methods of the SISO and MIMO systems by using PID control, and fuzzy. Typically, people use automatic PID tuning to derive the required control outputs of a system [3]. Although it is efficient and easier to use in the matlab/simulink environment there are some other methods also which can be used to achieve the desired control output [6]. Though the other methods may seem time consuming but when applied tends to give more better steady state value than the PID tuning. Here in this paper a comparative study has been performed between various methods for both the SISO and MIMO systems and some observations have been made based on the outputs.**

***Keywords*—SISO, MIMO, PID, Fuzzy, steady state, control**

I. Introduction

SISO (Single Input Single Output) and MIMO (Multiple Input Multiple Output) are fundamental concepts in control systems, especially in the context of system dynamics and feedback control. A SISO control system involves a single input and a single output. It is the simplest form of a control system, where one variable is controlled by manipulating one other variable [4]. The transfer function for a SISO system is:

$$G(s) = \frac{Y(S)}{U(S)}$$

A MIMO control system involves multiple inputs and multiple outputs. These systems are more complex but allow for more advanced control strategies, especially useful in multivariable processes. The transfer function for a SISO system is:

$$G(S) = \begin{bmatrix} G_{11}(S) & G_{12}(S) \ldots \ldots G_{1n}(S) \\ G_{21}(S) & G_{22}(S) \ldots \ldots G_{2n}(S) \end{bmatrix}$$

Here, we have used two load frequency control circuits as models for the MIMO and SISO systems. The load frequency circuits use a control area in their systems and the SISO and the MIMO depends on whether the control area used is one or two. Let's look at the issue of maintaining the scheduled frequency by managing the power output of the generators in a tightly knit electric area. In this case, every generator in the vicinity functions as a cohesive unit, varying in speed and amplitude simultaneously while preserving their respective power angles. A control area is an example of such an area.

The application of knowledge-based systems is growing especially in the field of Fuzzy control. A fuzzy system is a form of reasoning or decision-making system based on fuzzy logic, which extends classical Boolean logic to handle the concept of partial truth. Unlike classical logic, where variables must be either true or false, fuzzy logic allows variables to have degrees of truth represented by values between 0 and 1. This makes fuzzy systems particularly useful for dealing with uncertain or imprecise information.

In this paper PID control as well as Fuzzy method have been used to arrive a steady state for both the SISO and MIMO systems.

The figures used for the model in the paper are:

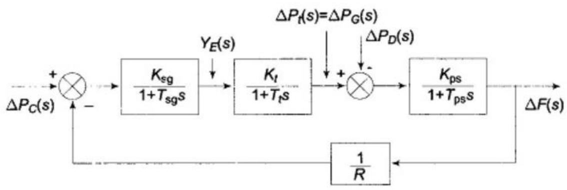

Fig 1: Block diagram of load frequency control for a single area

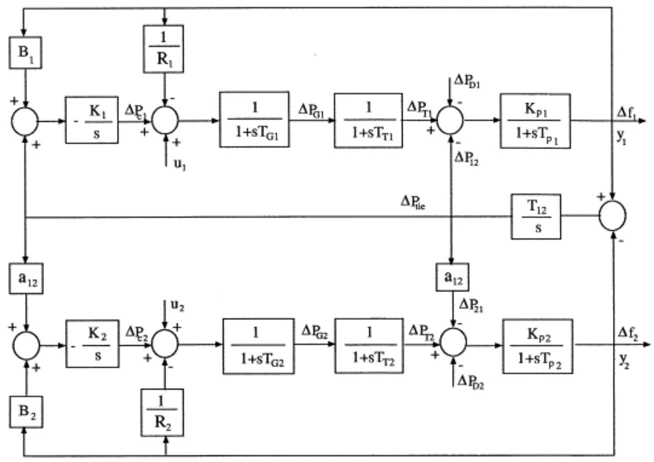

Fig 2: Block diagram of load frequency control for two area [1]

II. STEADY STATE ANALYSIS

The model indicates that the Load Frequency Control of a Single Area System receives two significant incremental inputs: ΔP_D, which represents the change in load demand, and ΔP_C, which represents the change in speed changer setting. Let us examine a basic scenario where the load demand fluctuates and the speed changer has a fixed value ($\Delta P_C = 0$). We call this process "free governor operation."

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The steady state change in system frequency can be obtained as:

$$\Delta F(S)|_{\Delta P_C(s)=0} = -\frac{K_{ps}}{(1+T_{ps}S)+\frac{K_{sg}K_tK_{ps}/R}{(1+T_{sg}S)(1+T_tS)}} \times \frac{\Delta P_D}{s}$$

$$\Delta f \left| \begin{matrix} steady\ state = \\ \Delta P_c = 0 \end{matrix} \begin{matrix} s\Delta F(s) \\ s \to 0 \end{matrix} \right|_{\Delta P_c(s)=0}$$

$$= -\left(\frac{K_{ps}}{1+(K_{sg}K_tK_{ps}/R)}\right)\Delta P_D$$

Let, $K_{sg}K_t \cong 1$

Also, $K_{ps} = {}^{1}/_{B}$, where $B = \frac{\delta P_D}{\delta f} P_r$

Then,

$$\Delta f = \left(\frac{1}{B+1/R}\right)\Delta P_C$$

If, the load demand changes by ΔP_D, then

$$\Delta f = \left(\frac{1}{B+1/R}\right)(\Delta P_C - \Delta P_D)$$

The frequency change by load demand can be compensated by changing the setting as $\Delta P_C = \Delta P_D$ [4].

III. Control Techniques

We have used two control methods to achieve a steady state value. The same values have been used for PID control in both the load frequency models. Similarly, for Fuzzy same rules and input-output values have been used for both the models to show how the outputs are different even though same values have been used.

A. *PID Control*

PID control stands for Proportional-Integral-Derivative control, a feedback control system widely used in industrial control systems and a variety of other applications requiring precise control of processes. PID controllers are valued for their simplicity and effectiveness in a wide range of control situations.

The transfer function of a PID control is given by:

$$G_c(S) = K_p + {}^{K_i}/_{S} + K_d S$$

Where K_p, K_i, and K_d are the proportional, integral and derivative gains, respectively.

The discrete time equivalent for PID control is given by:

$$u(k) = K_p e(k) + K_i T_s \sum_{i=1}^{n} e(i) + \frac{K_d}{T_s}\Delta e(k)$$

Where $u(k)$ is the control signal, $e(k)$ is the error between the response and the process output, and T_s is the sampling period.

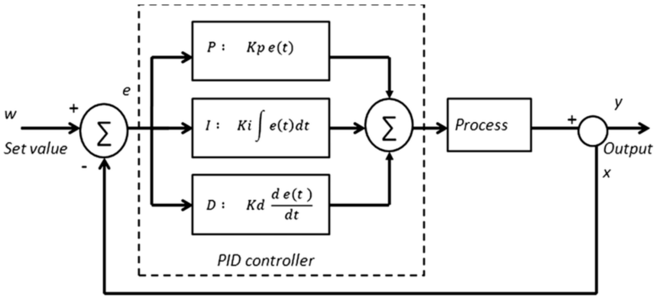

Fig 3: Block diagram of PID Control

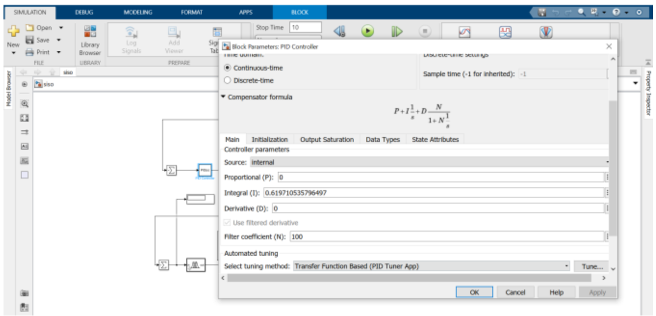

Fig 4: PID tuning used for the SISO model

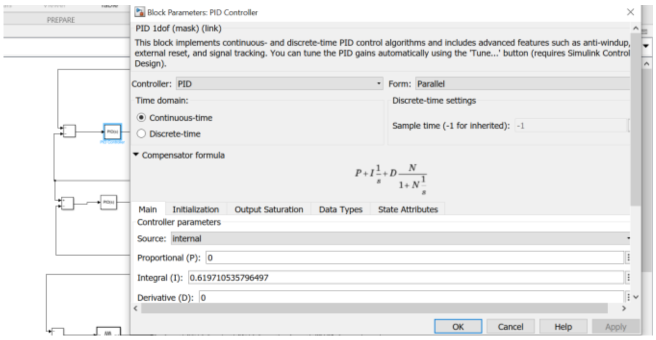

Fig 5: PID tuning used for the MIMO model

B. *Fuzzy Control*

The most active field of study for the applications of Fuzzy logic, Fuzzy reasoning, and Fuzzy set theory is Fuzzy logic control (FLC). FLC finds application in biomedical instruments, securities, and industrial process control. In contrast to traditional control methods, FLC has proven most effective when applied to intricate, ill-defined issues that a skilled human operator can effectively manage without having to understand the underlying dynamics.

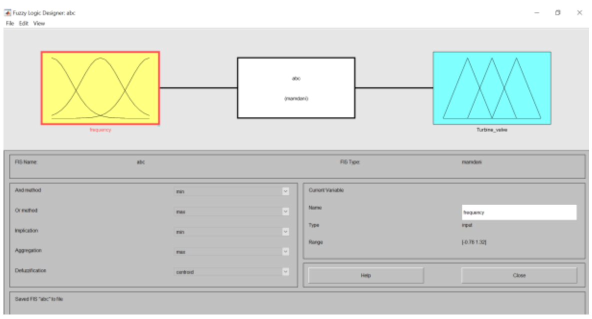

Fig 6: Fuzzy Logic design

We have used the Mamdani model here to implement the Fuzzy logic.
One of the most commonly used Fuzzy inference techniques is the Mamdani method. The Mamdani Fuzzy inference process is performed in four steps:

- Fuzzification
- Rule evaluation
- Aggregation
- Defuzzification

The Mamdani method is a widely recognized approach to expert knowledge capture. We can characterize the expert knowledge. It enables us to convey the expertise in a way that is more natural and intuitive for humans.

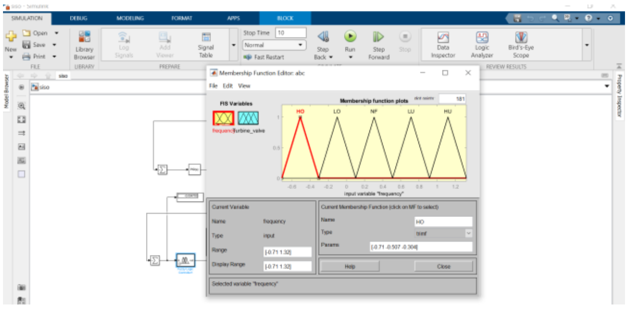

Fig 7: Input membership functions for the Fuzzy rules applied to both SISO and MIMO

The input membership function is taken as frequency.
The membership functions are taken as HO- High overshoot, LO- Low overshoot, NF- Normal frequency, HU- High undershoot.

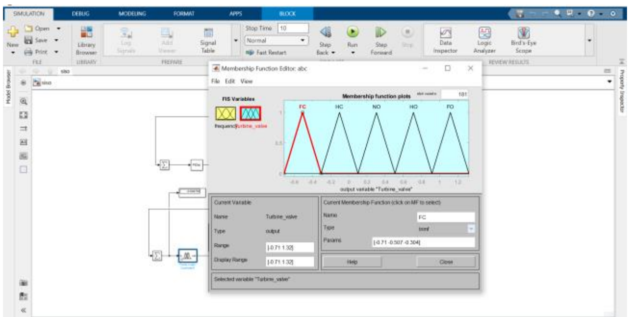

Fig 8: Output membership functions for the Fuzzy rules applied to both SISO and MIMO

The output membership function is taken as the position of the turbine valve.
The membership functions are taken as FC- Full close, HC- Half close, NO-Normal open, HO-Half open, FO-Full open.
The fuzzy rules may be applied as:

- If the frequency is HO, then valve position is FC.
- If the frequency is HO, then valve position is HC.
- If the frequency is LO, then valve position is FC.
- If the frequency is LO, then valve position is NO and so on.

The rules along with the input and output membership functions are taken and then used to achieve a steady state for the frequency.

C. OUTPUTS AND RESULTS

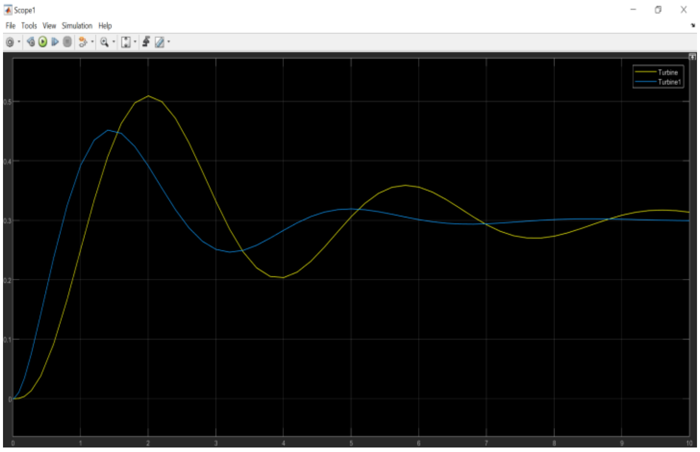

Fig 9: The results of the turbines in the SISO process after application of PID and Fuzzy control.

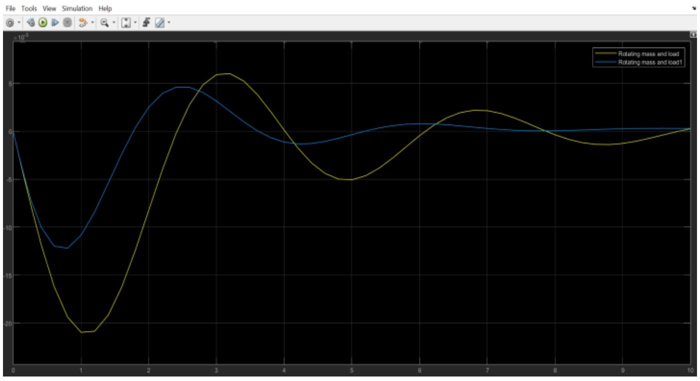

Fig 10: The results of the rotating mass and load in the SISO process after application of PID and Fuzzy control.

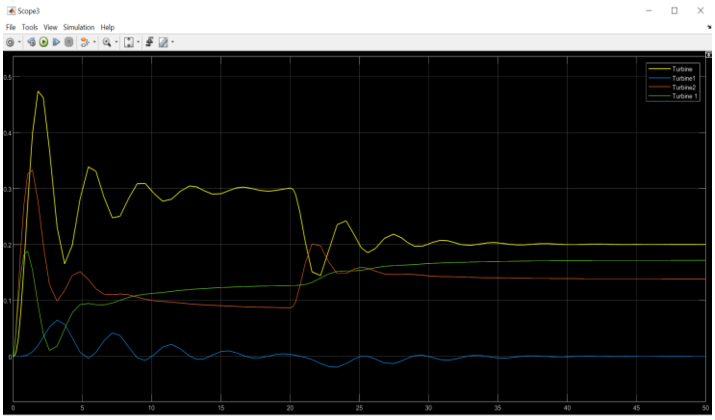

Fig 11: The results of the turbines in the MIMO process after application of PID and Fuzzy control.

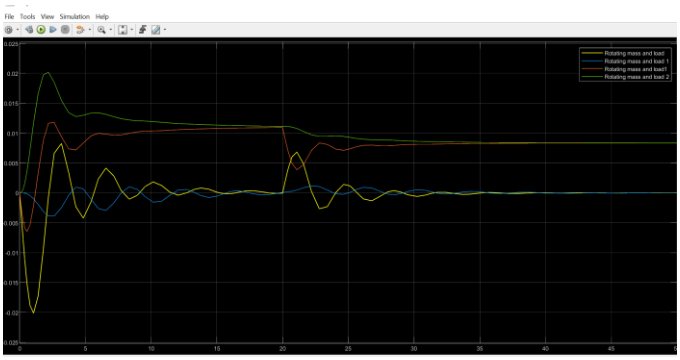

Fig 12: The results of the rotating mass and load in the MIMO process after application of PID and Fuzzy control.

D. CONCLUSION

It can be observed that although the same type of fuzzy rules or PID control has been applied to both the SISO and MIMO models. But in the SISO model the output of the mass tends to achieve a steady state value but it the MIMO system it is not so. The tie line in the MIMO model must be playing a role to differentiate the model variables.

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