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## Power system load frequency management using fuzzy logic



**Abstract:** - A power system is a sizable, intricately linked network that has multiple sources and loads. The population growth causes variations and unpredictability in load demand. The utilities are responsible for meeting load demand while abiding by operational restrictions on the power system. Control of load frequency is alone in charge of providing the customers with sustainable electrical power. Its primary purpose is to control system frequency and power flow in additional areas within advised bounds by controlling tie-line power and the utility generator's output power in reaction to changes in load without compromising system frequency. The paper's recommended concept illustrates the load frequency control of two area systems using fuzzy logic, fuzzy tuned proportional integral, conventional proportional integral, and proportional integral derivative controllers. SIMULINK is used for simulation research.

**Keywords:** PI controller, Frequency control, Fuzzy, Fuzzy Controller, PID controllers

### I. INTRODUCTION

The load demand and system complexity in modern power systems increase daily. Frequency deviation is caused by abrupt variations in demand, so it's vital to keep the frequency within the turbine speed-determined range of  $\pm 0.5$  Hz. The term "LFC error" refers to the frequency variation, which is a crucial component of AGC ("automatic generation control"). In order to ensure the power system's reliable function, if there are multiple locations, the tie lines between them must also be kept within the authorized bounds. [1, 4]. The most commonly utilized controllers in multi area systems [4], particularly in two area systems, are "fuzzy logic with PI controllers" [20], "fuzzy logic based PID controllers" [17], and "neuro-fuzzy controllers" [19]. Additionally, fuzzy controllers help the system regain its stability and robustness [7,8,12]. In addition to traditional controllers, newer controllers that use evolutionary algorithms [6,15,21] are important in AGC. The controller's design, which keeps the frequency variation at zero even with changing load conditions, has been examined amid a wealth of AGC research [13, 20]. Here, the constant frequency is maintained via a variety of controllers, including FTPI, FLC, PID, and PI. PID controllers are also utilized to lessen noise produced by LFC operation. It is more crucial to adjust the parameters of controllers when utilizing them. Ziegler-Nichol's tuning [16], self-tuning [1][3][10], and revolutionary method [9][11] are a few of the tuning techniques. Certain protocols for controller design have been offered by researchers [14]. To control load frequency, a variety of intelligent controllers were employed, such as neural networks [5], optimized fuzzy PID controllers [21], and others. The turbine, generator & governor, make up the two-area system model [2].

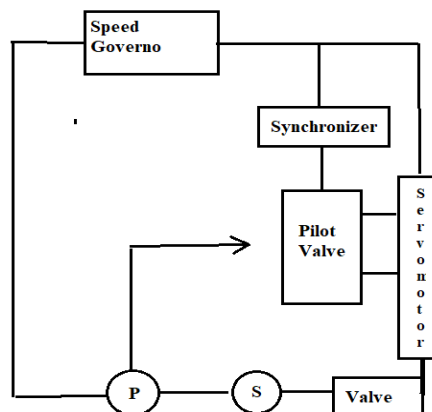


Figure-1 (Model of load frequency control using a single area network)

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Fig. 1 shows the physical depiction of the speed controlling mechanism. The primary tool for controlling load frequency is the speed governor. Large pressure steam flow in turbine may be regulated by adjusting the position of the control valve. The speed converter issues the raise command when the load increases and the turbine's speed drop. As a result, the fly ball speed governor moves outward, controlling the linkage mechanism and raising the turbine's steam input and, consequently, its power output. The linkage method to reduce the generation depends on the turbine speed increasing as the load drops and the speed modifier providing the lower grip. on the request [18]. Therefore, the generator's attached turbine speed is measured and controlled by the speed governor. The speed governor is regarded as the central component of the load frequency authority. One can regulate the flow of high-pressure steam to the turbine by adjusting the position of the control valve. A decrease in turbine speed is noticed as the load grows, and the speed modifier raises the signal or grip. In order to increase the steam i/p to the turbine and subsequently the creation of power, the fly ball speed governor moves outward, controlling the linkage mechanism. The linkage method to reduce the generation depends on the turbine speed increasing as the load drops and the speed modifier providing the smaller command. based on the request. The integration of the governor, turbine, and generator load models yields the block diagram of LFC for an isolated power system, as shown in Fig. 2.

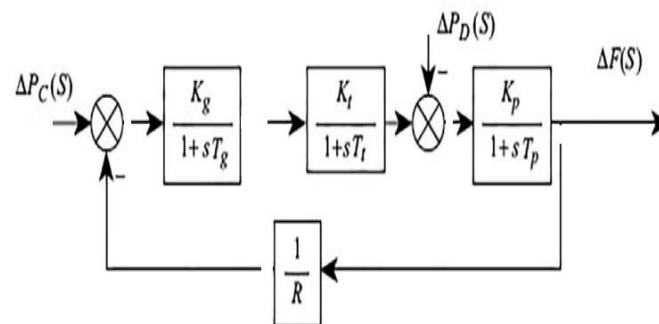


Figure-1

Where

- R - "Speed regulation of the governor in Hz/MW"
- K<sub>g</sub> - "Gain of speed governor"
- T<sub>g</sub> - "Time constant of speed governor, T<sub>g</sub> < 100 ms"
- T<sub>t</sub> - "Time constant of turbine"
- K<sub>t</sub> - "Gain constant"
- ΔP<sub>v</sub> - "Change in valve position"
- K<sub>p</sub> - "Power system gain"
- T<sub>p</sub> - "Power system time constant"

Multi area systems are those in which tie lines are used to connect multiple single area systems. A modest load shift in any location causes all of the turbine-generator units in the system to fluctuate combined with different batches of turbine and generator plants in different areas. These systems are characterized by the same frequency. The operation of the ligature joins the two zone of a "two-area power system", which is comparable to a "single area power system". Here, the tie line power and frequency variation are used to generate the command signal.

### Controllers in load frequency Control

PI controller - The most often used controller in industries is the proportional integral controller. The system's steady state error is decreased with its help.

PID Controller-

The industries also employ the Derivative controller and Proportional Integral to regulate their processes. The general purpose of it is to enhance the transitory reaction.

Fuzzy Controller- A broad range of machine control applications use fuzzy logic. The following are the several stages of a fuzzy system

Fuzzification in action: It is the procedure for converting the fuzzy controller's crisp inputs to a linguistic variable by leveraging the membership serve as a basis for fuzzy rules.

Defuzzification is the activity via which the language variables derived from the fuzzy directive foundation are transformed into a crisp o/p for use in the system's control operation.

Combination of Fuzzy & PI controller for the system's load frequency regulation, the fuzzy controller chooses the integral and proportional gains. Mathematical or trial-and-error methods can be used to calculate the gain values.

**Simulation output**

In two scenarios, simulation research has been done to design LFC controllers. In the previous instance, a trial-and-error approach was used to determine the enhanced values of the proportional integral and derivative controllers. Later, the Cohen-Coon method is used to acquire the benefit. The tie line that connects the two areas is part of the two-area power system. Table 1 lists the parameters and values for two sections. T12, the tie line time constant, is 0.086. Figures 3 show the frequency deviation simulation consequences for a 10.0 percent change in load demand using “PID, PI, and fuzzy” controllers, respectively. The input membership function is frequency error and difference in frequency error, and the controller's gain settings are Figures 4, 5, and 6 illustrate the corresponding membership functions.

When the load changes by 10%, different controllers' responses are tallied in Table 2. It demonstrates how utilizing a traditional PI controller reduces frequency deviation while employing a fuzzy controller minimizes settling time.

**Cohen-Coon controller tuning approach**

The cohen-coon method of managing tuning is used in the study to calculate the optimize values of the controller. The system's open loop represents yields the optimize value (k), delay time, and (td) and transient time (s) are computed and utilized in the modelling process.

The PI controller's Cohen-Coon formula is:

$$kp = \frac{1}{k} * \frac{\tau}{td} * (0.9 + \frac{td}{12\tau}) \text{ Eq-1}$$

$$ti = td (\frac{30 + \frac{\tau}{td}}{9 + \frac{\tau}{td}}) \text{ Eq-2}$$

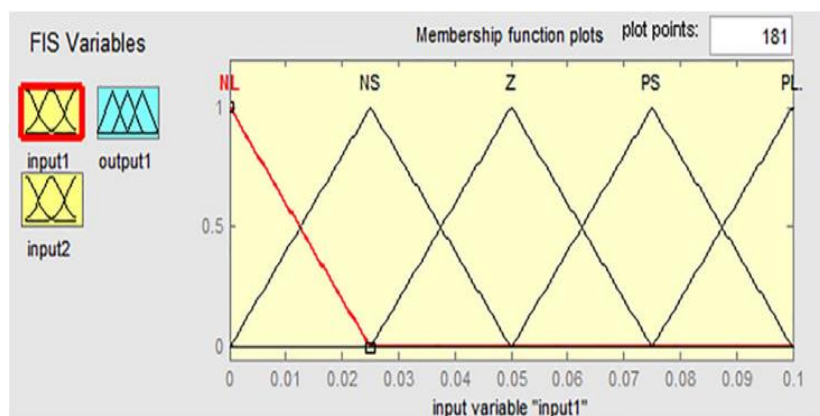
$$ki = \frac{1}{ti} \text{ Eq-3}$$

Table-1 “Two area system” parameter

“Parameters”	“Area-1”	“Area-2”
Kp	120.0	120.0
Tp	20.0	20.0
Tg	1.10	0.7
Tt	0.5	0.4
R	2.6	2.6
B	0.43	0.9

Table-1 Fuzzy, PID, and PI controller comparison.

Parameters	Fuzzy	PID	PI
“Settling Time”	21 Second	45 Second	72 Second
“Frequency deviation”	25 Hertz	22 Hertz	0.8 Hertz



**Figure-3.** I/P 1 membership Parameter

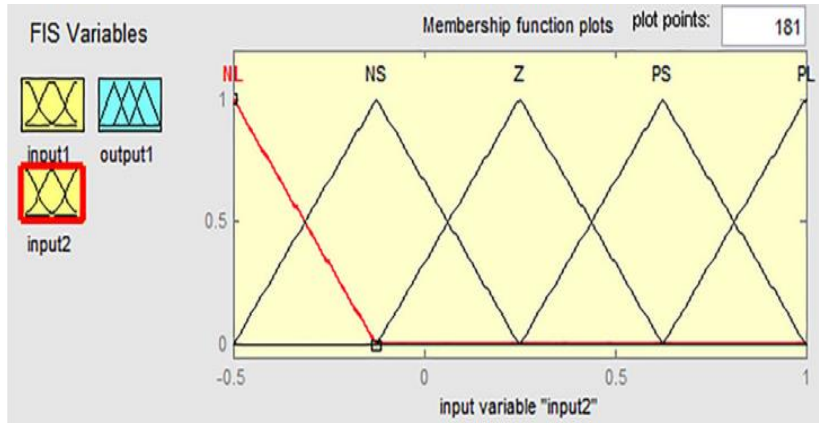


Figure-4 I/P 2 membership parameter

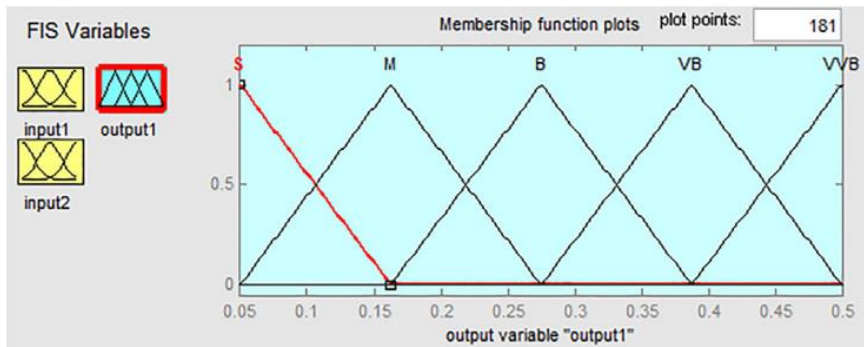


Figure-5 O/P membership parameter (“Open loop simulation of area 1”)

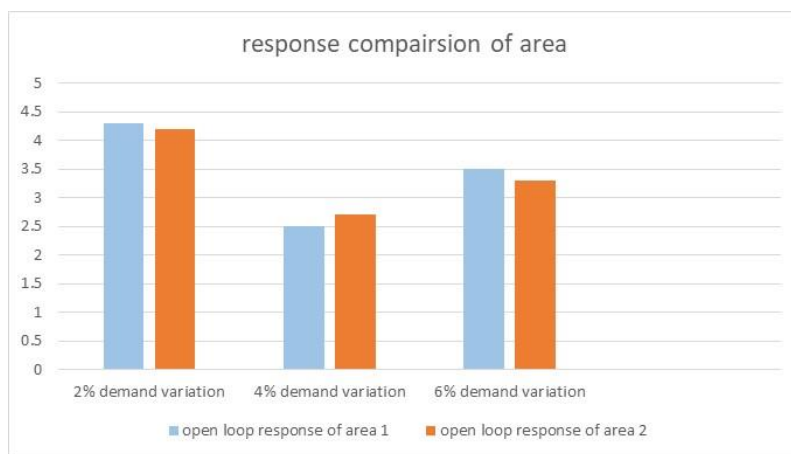
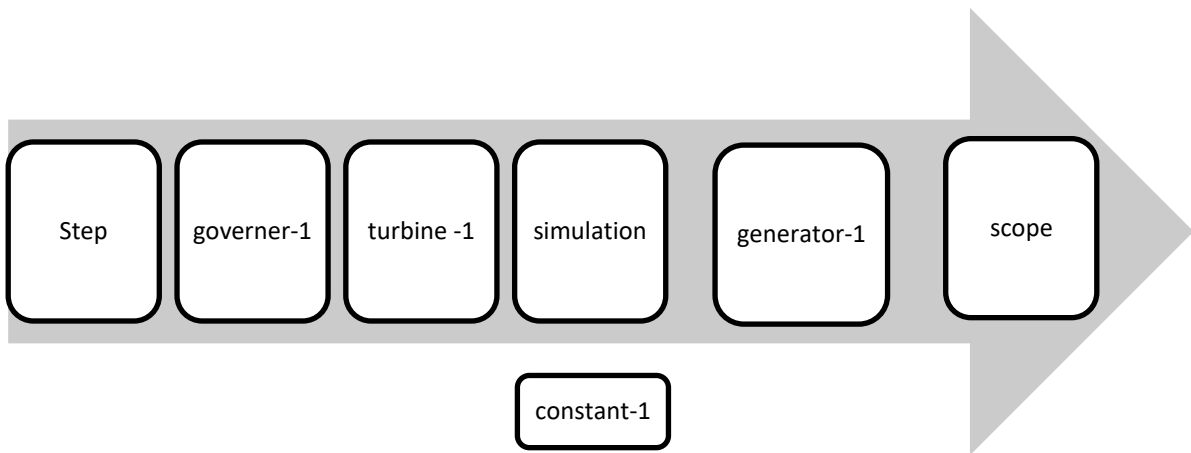


Figure-6

### Conclusion

Various controllers, including (“PI, PID, FLC, and FTPI”), are used to control the load frequency in single- and two-area systems. To valuation of controllers' accomplishment, a comparative analysis has been carried out. The findings have indicated that the Conventional PI controllers perform better at limiting frequency deviation, while FTPI controllers perform better at settling time. Because of this, the outcome is better with minimal frequency variation and minimum settling time when the PI controller and fuzzy controller's gains are varied based on the error signal.

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