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Load frequency control of multi area interconnected network with intelligent controller

Robin Jangra, Puneet Pahuja, Ashwani Kumar

Department of Electrical Engineering, Hindu collage of engineering Sonepat, India.

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Abstract

This research simulates the effects of three-area power system reconfiguration on frequency regulation. A tried-and-true classical load frequency control (LFC) methodology is offered to enhance performance of power system. The tie line power and frequency variation are reported using a reliable three-area power system. Both a PID controller and one without were created for this Simulink model. The system is transmitted from an initial state to the final form without tie line power and frequency deviation oscillations. In other words, the final steady state has an inaccuracy of zero. For three region power systems, these results are contrasted in terms of how the load is distributed across systems with and without integrated controllers. Software called MATLAB/SIMULINK is utilized for this application. A LFC issue results from the power system's load fluctuating over time and causing frequency variations. The frequency fluctuation is very unfavorable. The maximum allowed frequency fluctuation is ±0.5Hz. To address these issues, a new fuzzy LFC is represented to quench the frequency and tie-line power deviation owing to various load disturbances. In this study, the LFC is done by fuzzy control, that was faster than the PI controller.

1. Introduction

The load and generation profile in a control region can be maintained near-term using the LFC. By controlling the speed controller, it operates. The LFC is used to reduce deviations and errors to zero. The average energy is converted into electric power in the Power framework [1-3]. It is typically necessary to transmit power using a three-phase alternating current (A.C.). However, this could be done by balancing the reactive and active power on the generation and use sides. Voltage and frequency are each affected separately by active and reactive power. While the voltage relies on active power, the frequency primarily depends on reactive power [4, 5]. Because of this, a control strategy must be used in a power system for both frequency control, which results in possession of active power, and voltage control, which results in reactive power management. To maintain frequency, the generators in control locations change often. A frequency deviation like a tie-line or interconnected power deviation will occur if the load in the control region is abruptly altered [6-9]. For a power structure to maintain a regular and dependable activity, it must be in operation. Disasters like the power blackout in July 2012 in India due to dissatisfaction with keeping up as feasible across grids, might result from deviation from the optimum repeatItalia, Southern Brazil, the Northeastern United States, and Canada all experienced blackouts due to the shift in occurrence. Transient reactions are further encouraged by standard regulators, such as PID, in the available System of

Corresponding author: Robin Jangra
Email Address: jangraaakash5@gmail.com
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Load Flow power. With a proportional-integral controller, a better edge of unwavering quality is guaranteed. With zero overshoot, the proportional integral controller produces a dependable state blunder. Recurrence control refers to the problem of regulating the actual output power of forming units due to variations in structural repetition and tie-line power not fixed in explicit stone emphasis. LFC aims to provide zero dependable state error of duplication and tie-line trade variety, high repeat motion damping, and reduced aggravation overshoot, so the framework isn't unreasonable far from security. A power structure is frequently divided into control areas, each of which has at least one association with a utility of power. Adequate supply for individually associated location to meet customer load requirements [10]. The lately mentioned goals have been effectively transmitted in earlier works by many creators employing P.I. and PID controllers. For improved repeat replies, the PID-tune controller is employed in this research. This controller is used by this power arrangement, decreasing steady-state error. Using this controller never results in a dependable framework load. When the uncontrolled situation wavers more, negative overshoot is observed still while behaving differently than the usual regulator PID, and the proposed work result delivers better presentations of dynamic reactions, these may be managed. Recurrence was already being restricted by standard P.I [11-15]. regulators the previous year. Fuzzy logic was developed after much research and is strongly supported in the controller's arrangement. The power framework became more reliable and deducible from this regulator because of the widespread usage of fuzzy logic; it also executed more quickly than the traditional one. The literature suggests controllers based primarily on FLC, conventional P.I., and fuzzy P.I., Numerous studies on various regulating networks, have specific benefits and drawbacks [16, 17]. Most publications use a standard PID controller to manage the load frequency, and it is noted that this PID controller performs better than others. Conventional controllers, however, fail to produce a better outcome when non-linearity in a power system is considered. In this situation, PID controllers may readily take the role of intelligent controllers to provide quick and accurate dynamic responses.
Because they operate more quickly and efficiently in nonlinear situations than traditional controllers, fuzzy logic controllers are more beneficial.

2. Literature on LFC related power system model

Studies on the load recurrence power of power framework have been accessible for over thirty years. Hydro-hydro Power framework and replication model have been proposed, together with a linearized model of multi-region (counting two areas) power frameworks [1]. They assume the same frequencies to overcome the challenges of expanding the traditional technique. Disregarding the differences in recurrences between the power areas, we studied the LFC of the linked force framework and investigated the detailing of LFC by LCT [2] to represent the model. The influence of (GRC) on these exams was then discussed, considering both discrete and continuous power frameworks. Effect of non-direct tie line bias features in execution [3].

2.1 Literature on LFC related to control technique

A thermal, hydrological system model and artificial intelligence algorithms were developed. An advanced control approach for an interconnected multi-area power system for FLC, and LFC is applied to reduce changes in system output. Power systems often consist of many zones, each distinct from the others. Three thermal units comprise the electricity structure for three areas—power system frequency management utilizing the best output feedback technique. Recurrence and voltage are directly impacted by the dynamic force and responsive force effect; the control issue between recurrence and electrical energy may be separated. It provided three models and used clever strategies to adjust their frequency. The LFC is tied to an interrelated warm framework, and LFC has received somewhat less attention than it deserves. The PID, which is simple to use and provides superior dynamic responsiveness, was applied to the three sections of the linked system. However, their performance occasionally declines when the system's difficulty rises due to turbulence. Use artificial intelligence methods like fuzzy logic controllers to overcome this issue. The thermal hydro system's interconnectivity is depicted in this study: unique burden qualities and boundary variety/vulnerabilities. Due to the modern electrical system's complex configuration, any shaking might spread to large areas, resulting in a system blackout. Advanced control techniques, including intelligent control, self-tuning control, adaptable control, construction control, and ideal control, were used in this particular situation to address the LFC issue [18, 19]. The adjusted integral derivative regulator was suggested in an open environment for the LFC of a multi-regional multi-source power framework. In any case, the framework state vector may be seen through region measurement, which necessitates the accessibility of all state variables to produce the feedback signal. The ongoing study by several control design experts has resulted in connections between the closed-loop rapid reaction (in time-space) and recurrent reaction. Diverse classic control approaches are used to continue the evaluation. It will be found to have a tremendous impact on overshoot and temporary recurrence variation. Additionally, the framework's settling period for recurrence variation is often comparably long. The LFC ideal controller plan inspires experts in control designing approaches using superb control hypotheses to develop control frameworks with ideal regulators for specific execution models [20-22]. The force arrangement of two identical regions connected by a tie line and equipped with a non-warm turbine is monitored for analysis. The earlier writers measured the LFC issue for comparable frameworks from an ideal stochastic approach. The power framework for the process' equally little and significant sign ways was presented more effectively through a calculation that relied on the control procedure. To identify the LFC problem inside a network of connected force frames that uses the GWO technique to transmit a standard

PI/PID regulator. While defining the control aims, and the performed model technique has allowed for crucial adaptability while rejecting any data from framework networks. It further avoids the solution of the mathematical Riccati requirement. The AGC controller, excitation regulator plan and execution command address the LFC issue by employing experts at various points concerning boundary variety/vulnerabilities and load characteristics. Due to the complex nature of the sophisticated force framework, swaying brought on by exposure to any disturbing effect might spread to large areas, making the framework black [23, 24]. Advanced control techniques, including ideal control, changeable construction control, intelligent control, adaptable control, and solid control, were influential in this particular case regarding the LFC issue.

3. Mathematical model of speed governing system

The elect force increases the mechanical force input when the load on the electric generator unexpectedly increases. The K.E. stored in a revolving system provides the power shortage. A decline in K.E. results in a reduction in the turbine's speed and, as a result, in the generator's recurrence. The turbine governor, which alters the turbine i/p—valve to change the mechanical power output to convey the speed to a current consistent condition, detects the rate modification. The watt governor was the previous governor, and it employed revolving flyballs to gauge the speed of the governor and give mechanical movement as a result of advancement.

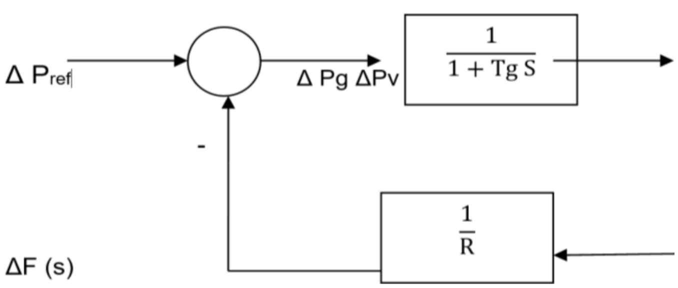

Figure 1: Steam turbine governing system.

$\Delta Y_E(s) = [\Delta P_C(s) - \frac{1}{R}\Delta F(s)] \times \frac{Kg\, s}{1+sTgs}$

3.1 Mathematical modelling of Turbine

Gas turbines, burning control, and nuclear fuel are employed to drive the steam turbines. Prime movers are frequently thought of as the source of mechanical power. The mechanical power o/p (ΔPm) and steam valve position (ΔYE(s)) change to determine how the turbine model is represented.
The Tt lies between the range 0.4 to 2.5 sec.

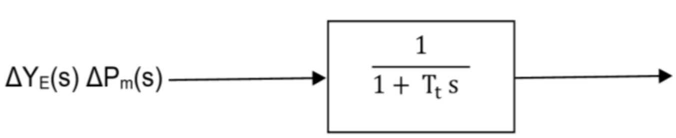

Figure 2: Turbine model block diagram.

3.2 Generator load model

Increased power input to the generator load structure is correlated with an increase in frequency.

$\Delta F(s) = \Delta P_m(s) - \Delta P_D(s) \times \frac{1}{2Hs+D}$

3.3 Nuclear Power plant turbine modelling

The type of power facility that uses atomic fission to produce energy is known as a nuclear power plant. The speed governor, turbine, and generator should be modelled for the nuclear power system LFC.

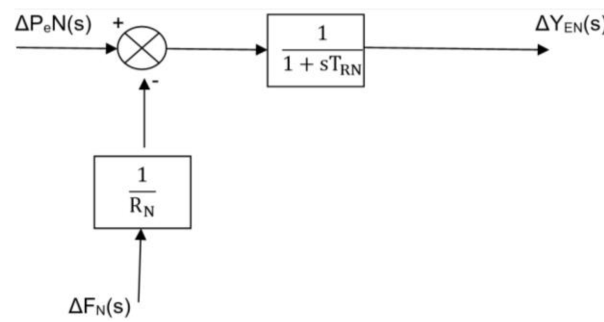

Figure 3: Transfer function of governor

3.4 Hydro-Thermal interrelated system

The LFC of the power system plays a vital role in generating electricity. The power framework is segmented into various load recurrence control zones connected by tie lines. The primary goal is to regulate tie line electricity by region and the occurrence in every location. It will provide a steady state variance in frequency in the primary LFC loop. It depends on the lead representative's speed guidelines. Therefore, to reduce this recurrence deviation to zero, we must provide reset activity and control activity to manage these frequency deviations. To do this, we must present the necessary controller in the plant to monitor the load reference setting and adjust the speed set point. By multiplying the framework type by 1, the primary regulator drives the latest recurrence deviation to zero.

The modelling of thermal speed governor is

$\Delta Y_E(s) = [\Delta P_C(s) - \frac{1}{R}\Delta F(s)] \times (\frac{K_{gs}}{1+ST_{gs}})$

Modelling of thermal generator is

$\Delta F(s) = [\Delta P_G(s) - \Delta P_D(s)] \times (\frac{K_{PS}}{1+sT_{ps}})$

Where,

Kgh	Gain of Governor speed
Tw	Starting time of water
Tgh	Time constant of Hydraulic speed governor

Bi	Frequency Biasing Parameter
Kp	Load
Tr	Constant of reheat time
Tt1	Time constant of steam turbine
Tg1	Time constant (speed governor) of thermal plant

The transfer function of thermal load may be written as

$$\Delta F(s) = \Delta P_m(s) - \Delta P_D(s)\left(\frac{1}{2Hs+D}\right)$$

A speed governor, turbine, and generator model were necessary for the hydroelectric power framework used to demonstrate LFC. The pressure-driven opposition is assumed to be inconsequential, the penstock pipeline is considered to be inelastic, and water is assumed incompressible to provide a stable depiction of the hydraulic turbine and water column.

T.F of hydro turbine is shown as $\frac{\Delta P_{Th}}{\Delta Y_{eh}} = \frac{1-sT_w}{1+0.5sT_w}$

Transfer function of hydroelectric governor is

$$T_{Gh} = \left(\frac{K_{gh}}{1+sT_{gh2}}\right)\left(\frac{1+sT_{h2}}{1+sT_{h4}}\right)$$

Load model for hydro system

$$\Delta P_{e=} = \Delta P_L + D\Delta w$$

The results were obtained by using techniques i.e, like PI, AI, Fuzzy Logic Controller etc.

4. Controlling Methods

4.1 Conventional PI Controller

The PI controller is the most often employed control legislation in the hydroelectric and thermal plant operating framework. The PI controller can quickly reach a consistent state with the suitable controller because of its quicker transient responsiveness. The framework error gives the balanced control signal. High upsides of Kp produce more incredible consistent state performance when there is a step shift in load demand. In contrast, low upsides of Kp give steady responses with significant, consistent mistakes. Higher values of Kp are used in this way to minimize consistent state error, regardless of whether raising Kp's gain also lowers time constant and system damping issues later on. Therefore, choosing the proper "Kp" rate is crucial. The consistent state mistake in the framework is still there despite the direct proportional action being kept since many faults should be able to construct a control o/p. One method of lowering the constant error is using an integral in the controller. In this case, the essential elements of the error signal are matched by the produced control signal.

$$U(t) = K_i \int e(t)dt$$

Where Ki stands for gain in the presence of mistake. Additionally, once the error disappears, the integrator gives continued usage toward maintaining the ctrl activity, which is necessary for stable state circumstances. But even so, overshoot will increase as a component of growth if Ki addition is significant, which is very unfavorable. Overshoot is reduced by a lower value of Ki, while the rise time of the structure is lengthened. According to the conversation, Kp and Ki are both adequately designed. Traditional controllers are essential for execution and provide more distinctive responses. Their display, however, falters when the complexity of the framework rises due to load fluctuation disturbance. In light of this, a controller that can resolve this problem is required. It would be better to use fuzzy logic controllers.

Gc (s) = Kp (1 + 1/sT i)

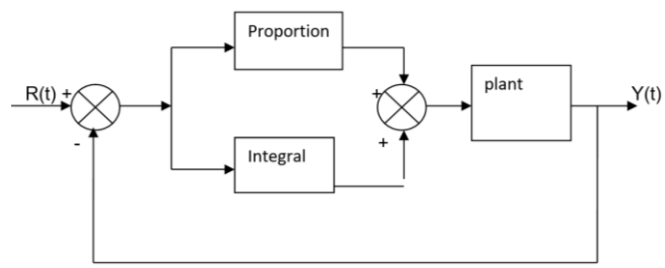

Figure 4: PI Controller block diagram

5. Results and Discussion

The PI and fuzzy logic controller simulated the data using the appendix's settings. The modelling of load frequency regulation using PI and a fuzzy logic controller was performed using "MATLAB" in the section below. Below is an illustration of the combined impact of two regionally interconnected thermal power frameworks. Take a break three-region structure with connections. At this point, the time required to reach a stable state of esteem is in the order of seconds because thermal and hydropower frameworks include mechanical types of gear that have additional time constants when they appear differently from electrical devices. This results in thermal energy stations with hydro plants and nuclear plants performing in tandem for a minor interruption in either region of "step 1 %" disturbance.

- The effects on both the area and a 1% disruption in a nuclear or hydroelectric plant
- When a thermal plant has a 1% disruption, both plants are affected
- Construction of a nuclear or hydroelectric facility when a thermal plant has a 1% interruption.
- Three locations are used for simulation, and three different results are obtained:
- The impact of a thermal plant when a nuclear or hydroelectric plant is disrupted by 1%.
- The result of any disruption in the thermal plant in all three sectors.

- The impact of a thermal plant disruption on a nuclear plant.
- The outcome of a nuclear plant when a thermal plant is disturbed.

5.1 Two regions of Thermal-Hydro System

Result Parameter of Hydro by using PI and FLC when 1% disturbance occur in Thermal, by using PI Controller.

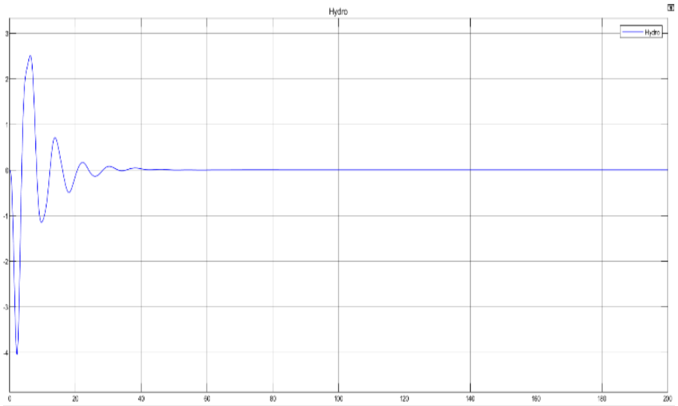

Figure 5: Output parameters hydro-plant at 1% disturbance occur in thermal plant

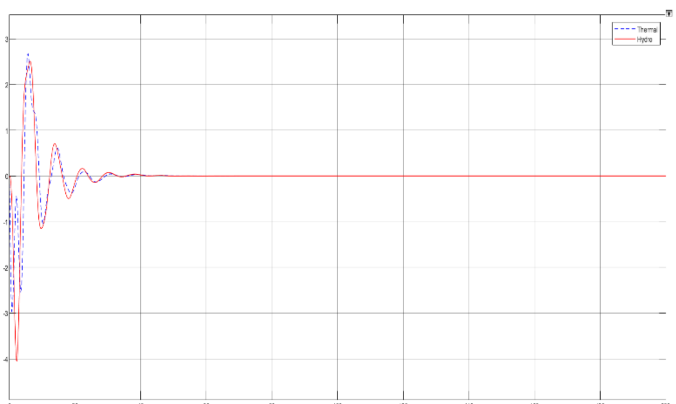

Figure 6: Output parameter of both the area at 1% disturbance occur in thermal plant

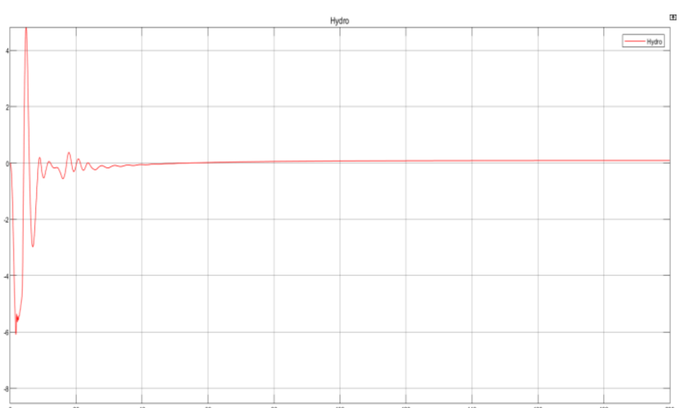

Figure 7: Output results hydro-plant at 1% disturbance occur in thermal plant by FLC

The Thermal-Hydro linked power system's tie line results are shown in Case 1. This outcome was obtained using MATLAB. Region 1 is where the interruption, FLC, and PI Controller occur. We employ controllers to attain steady state frequency because the graph illustrates the impact of frequency in area 2 due to a disturbance in area 1. And we see that the PI Controller takes longer to stabilise at a constant level than the Fuzzy Logic Controller. In this situation, the PI Controller's reaction is weak, and the Fuzzy Logic Controller settles more quickly. Table 1 above compares deciding times. The value of the rated frequency is shown by zero.

Table 1: Different parameters of hydro plant

Parameters	FLC controller	PI Controller
Minimum Overshoot	-6.10	-6.529
Maximum Overshoot	4.566	4.856
Settling Time (sec)	50	60

5.2 Two regions of thermal Nuclear System

Nuclear power plant result parameter utilizing PI and FLC when 1% disturbance occurs in thermal power plant using PI Controller.

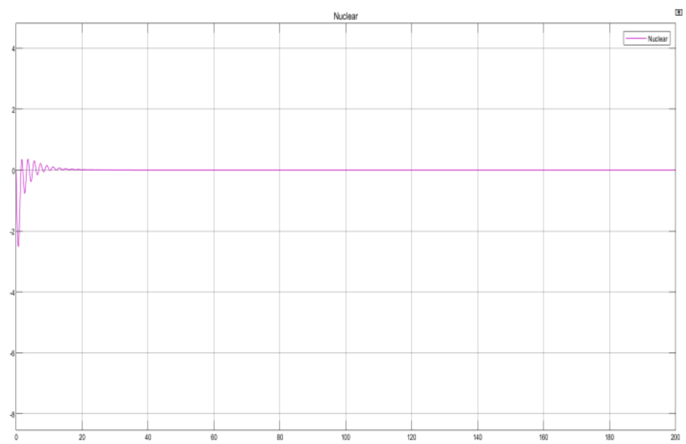

Figure 8: Output response of nuclear plant at 1% disturbance in thermal plant by PI

Figure 9: Output responses of both areas at 1% disturbance in thermal plant by PI

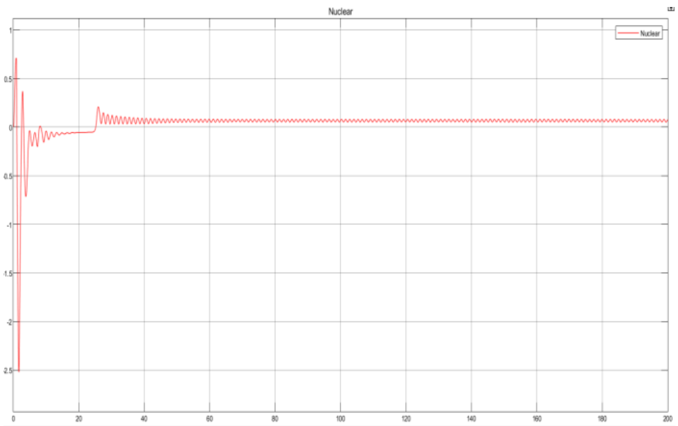

Figure 10: Output responses of nuclear plant at 1% disturbance in thermal plant

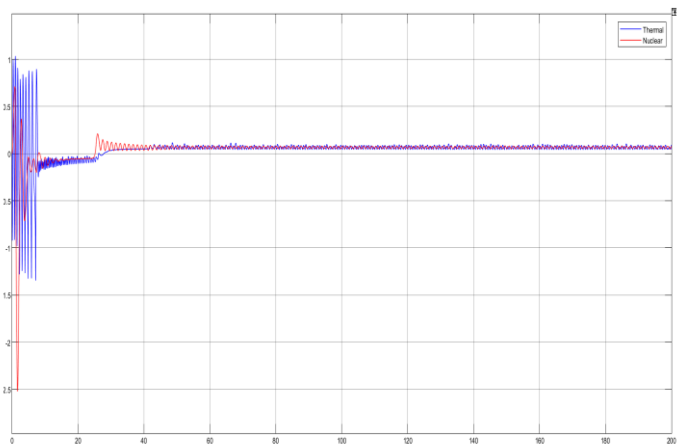

Figure 11: Output responses of both areas at 1% disturbance by FLC

Table 2: Different parameters of nuclear plant

Parameters	FLC controller	PI Controller
Minimum Overshoot	-2.6	-3.178
Maximum Overshoot	0.9	1.08
Settling Time (sec)	19	60

The end outcome of the thermal-nuclear power system's tie line interconnection. Once more, the frequency is maintained at a steady level using the Controllers. Here, it illustrates how area 2 is affected when there is a disturbance in area 1. When utilizing PI Controller, area 2 settles in 60 seconds, whereas FLC settles in 19 seconds. FLC makes decisions faster than PI Controller, which takes longer to resolve.

6. Conclusion

The various benefits also occur when two or more plants are connected, i.e., In a power framework organisation, there are only a few outdated and insufficient production facilities available that can handle a brief peak load. Still, these production facilities are sufficiently decrepit not to operate continuously. If the framework is linked, the transmission line connects these plants, which are used to meet peak load requirements and to supplement the existing plants. Using outdated and insufficient production facilities may satiate top burden requirements without placing extra stress on newer plants. The producing station operates at the same voltage and repetition rate. The power plant's interconnection works reliably and effectively. All loads have more than one supplier in the power framework's connectivity. In this situation, the load is delivered from a separate source if one inventory is failed. For this reason, the load is connected to additional healthy power stations if a significant power station breakdown occurs. As a result, the load is continually connected to a steady power source, improving system reliability. With a 1% disturbance, the Fuzzy Controller responds quickly, and its settling time is likewise shorter, demonstrating that FLC reacts more powerfully than a PI regulator. With a fuzzy regulator, the transient's reaction was greatly reduced.

References

[1] George Gross and Jeong Woo Lee, "Analysis of Load Frequency Control Performance Assessment Criteria", IEEE transaction on Power System Vol. 16 No, 3 Aug 2001

[2] D. P. Kothari, Nagrath" Modern Power System Analysis"; Tata mc Gro Hill, Third Edition, 2003.

[3] Y. Arya, N. Kumar, and S. Sinha. Fuzzy logic based load frequency control of multi-area electrical power system considering non-linearities and boiler dynamics. International Energy Journal, 13(2), 2012.

[4] E. C¸ am and I. Kocaarslan. Load frequency control in two area power systems using fuzzy logic controller. Energy conversion and Management, 46(2):233–243, 2005.

[5] H. Shayeghi & H.A. Shayanfar, "Power system load frequency control using REF neural network based on f/-Synthesis theory". Proceeding of IEEE conference on cybernetics and intelligent system Singapore, 1-3 Dec 2004, pp 93-98, 2004.

[6] H. Shayeghi, HA Shayanfar & A Jalili, "Load frequency control strategies: A state-of-the- art survey for the researcher" Energy Conversion and management 50, pp 344-353, ELSEVIER, 2009.

[7] J. Nanda, B. L. Kaul, "Automatic generation Control of an Interconnected Power System", IEE Proc., vol. 125, No.5, pp. 385-391, May 1978.

[8] J. Nanda, M. L. Kothari, P. S. Satsangi, "Automatic Generation Control of an Interconnected Hydrothermal System in Continuous and Discrete modes considering Generation Rate Constraints", IEE Proc., vol. 130, pt. D, No.1, pp 17-27, Jan. 1983.

[9] G. Chen, "Conventional and fuzzy PID controllers: an overview", International Journal of Intelligent and Control Systems, 1, 1996, pp. 235±246. [4] C. Concordia and L. K. Kirchmayer, ―Tie – line power and frequency con-trol of electric power system: Part II‖ AISE Trans, III-A, Vol. 73. pp. 133 – 146, Apr. 1954.

[10] Talaq J, Al-Basri F. Adaptive fuzzy gain scheduling for load-frequency contro[10] Rajendra Fagna, Load Frequency Control of Single Area Thermal PowerPlant Using Type 1 Fuzzy Logic Controller, Science Journal of Circuits, Systems and Signal Processing. Vol. 6, No. 6, 2017, pp. 50-56.

[11] M. Lokanatha, K. Vasu, 2014, Load Frequency Control of Two Area Power System using PID Controller, International Journal of Engineering Research & Technology (IJERT) Volume 03, Issue 11 (November 2014)

[12]] E.S. Ali , S.M. Abd-Elazim , Bacteria foraging optimization algorithm based load frequency controller for interconnected power system. Electrical Power and Energy Systems 33 (2011) 633–638. l. IEEE Trans Power Syst 1999;14(1):145–50.

[13] Ertu_grul C_am , _Ilhan Kocaarslan , Load frequency control in two Area power systems using fuzzy logic controller , Energy Conversion and Management 46 (2005) 233–243.

[14] SuryaPrakash ,SK Sinha, "Impact of slider gain on Load Frequency

Control using Fuzzy Logic Controller" ARPN Journal of Engineering and Applied Science, Vol4,No7, Sep 2009.
[15] John Y , Hung, " *Variable Structure Control: A Survey*", IEEE Transaction on Industrial Electronics, Vol. 40, No.1 Feb 1993.
[16] Ashok Kumar, O.P. Malik., G.S. Hope. "*Variable-structure-system control applied to AGC of an interconnected power System*" I.E.E.E. *proceedings, vol. 132, pt. c, no. 1, january 1985*
[17] Fosha C.E., Elgerd O.I., The megawatt – frequency control theory, IEEE Trans. Power Appl. Syst. (1970) Vol.89, pp. 563 – 571.
[18] Lee CC., fuzzy logic in controller part –II, IEEE Trans. Syst., Man Cybern (1990), Vol. 20 (2), pp. 419 – 435.
[19] Kundur P. Power system stability and control. McGraw-Hill; 1994.
[20] Hassan Yousef, "Adaptive fuzzy logic load frequency control of multi-area power system", International Journal of Electrical Power & Energy Systems Volume 68, June 2015, Pages 384– 395, January 2015.
[21] Anand B., Ebenezer A. Jeyakumar, "Load frequency control with fuzzy logic controller considering non-linearities and boiler dynamics", ICGST-ACSE Journal, ISSN 1687-4811, Volume 8, issue 111, pp 15-20, 2009.
[22] T.C. Yang, Z.T. Ding, and H. Yu, "Decentralised power system load frequency control beyond the limit of diagonal dominance," Electrical Power and Energy Systems, vol. 24, no. 3, pp. 173-184, 2002.
[23] H. Cimen, "Decentralised load frequency controller design based on SSVs," Turkish Journal of Electrical Engineering & Computer Sciences, vol. 8, no. 1, pp. 43-53, 2000.
[24] E. Cam and I. Kocaarslan, "Load frequency control in two area power systems using fuzzy logic controller," Energy Conversion and Management, vol. 46, no. 2, pp. 233-243, 2005.

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