ISSN 2277 – 5528
Impact Factor- 4.015

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & MANAGEMENT

Analysis of controllers for automatic generation control of two area interconnected power system

Aabha Chandravanshi* and H.S. Thakur
Shri Shankaracharya Institute of Technical & Management, Bhilai, (CG) - India

Abstract
This work presents a brief review and performance comparison of various controllers utilized in past few years for the automatic generation control of the two area interconnected power system. So many controllers like conventional controllers (I, PI, PD, and PID), soft controllers,and fuzzy logic based controllers; fuzzy tuned PID controllers etc. have been utilized for controlling the flow of power in the tie line. In this work fuzzy tuned PID controller is analyzed as the control structure in two area interconnected power system and study is extended for the transient response of the proposed system. In this paper all the prominent controllers and their characteristics have been studied and found that the fuzzy tuned PID controller with PSO technique provides better stability and dynamic response for the system compared to the other existing controllers.

Introduction
Two area control system is the interconnection of power systems which are interconnected through the tie-line. When two utility systems are interconnected one system is to be able to transact the power with neighboring system whose operating costs make such transaction profitable. If one system experiences a sudden loss of a generation, the units throughout all the interconnection will experience a frequency change and can help in restoring frequency [1].
area tie-line Area2

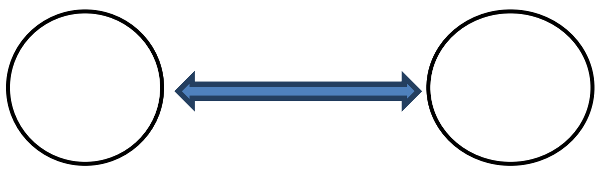

Fig.1. Two area system[2]

In the power system, electrical generator converts mechanical energy into electrical energy, and prime mover, that drives the generator, convertsfuel energy into electrical energy. Automatic generation control has three major objectives,

1. To clamp the system frequency at or close to a specified nominal value,
2. To maintain the interchange of power between the control areas.
3. To maintain each unit's generation at the most economic value.

Control areas control load and generation of an interconnected system. Mainly two types of control loops are available such as, primary control (load frequency control), secondary control (automatic voltage regulator) [2].

Designed Controllers for Two/multiple Area Interconnected Power System.
In a generating unit load is supplied by an isolated system. The change in load brings about the change in speed and magnitude of frequency.Frequency change with load is represented by the droop characteristics of the governor.When change in the system occurs, mainly work of the supplementary control reset of frequency to nominal value. This can be accomplished by adding a reset control to the governor. Reset control action means frequency error to be zero by supplementary controller. So, different controllers use in power system and analysis, which controllers (I, PI, PID and Fuzzy PID) give better performance and stability of the system [3].

A.In AGC of interconnected two equal areas and three unequal area with 3%/ min of generator rate constraints with single reheat turbine. Integral (I), proportional-Integral (PI), Proportional- Integral- Derivative (PID) and Integral-Double-Derivative (IDD) used in AGC. These controller parameters are optimized by using BF (Bacterial Forging) technique [2]. According to analysis and performance of controllers, it observed that Integral-Double-Derivative controller gave much better performance to other (I, PI, PID) controller and this controllers provided more or less same response [4].

System Investigation

In this work, two equal area system of area1: 2000MW; Area2: 2000MW and three unequal areas system of area1: 2000MW, area2: 4000MW and area3: 8000MW provided with single reheat turbine and generator rate constraints of 3%/min. Bacteria forging technique use for optimization, it is a more recent and powerful evolutionary computation technique. The control system of these bacteria that dictates how foraging should proceed. It can be subdivided into four sections namely chemo taxis, Swarming, Reproduction and Elimination and dispersal [5].

Chemo taxis: This process is achieved through swimming and tumbling via Flagella. Depending upon the rotation of Flagella in each bacterium, it decides whether it should move in a predefined direction (swimming) or altogether in different directions (tumbling), in the entire lifetime. To represent a tumble, a unit length random direction, say φ (j), is generated; this will be used to define the direction of movement after a tumble.

Swarming: During the process of reaching towards the best food location it is always desired that the bacterium which has searched the optimum path should try to provide an attraction signal to other bacteria so that they swarm together to reach the desired location. In this process, the bacteria congregate into groups and hence move as concentric patterns of groups with high bacterial density.

Reproduction: The least healthy bacteria die and the other healthiest bacteria each split into two bacteria, which are placed in the same location. This makes the population of bacteria constant.

Elimination and Dispersal: It is possible that in the local environment the live of a population of bacteria changes either gradually (e.g., via consumption of nutrients) or suddenly due to some other influence. Events can occur such that all the bacteria in a region are killed or a group is dispersed into a new part of the environment. They have the effect of possibly destroying the chemotactic progress, but they also have the effect of assisting in chemo taxis, since dispersal may place bacteria near good food sources.

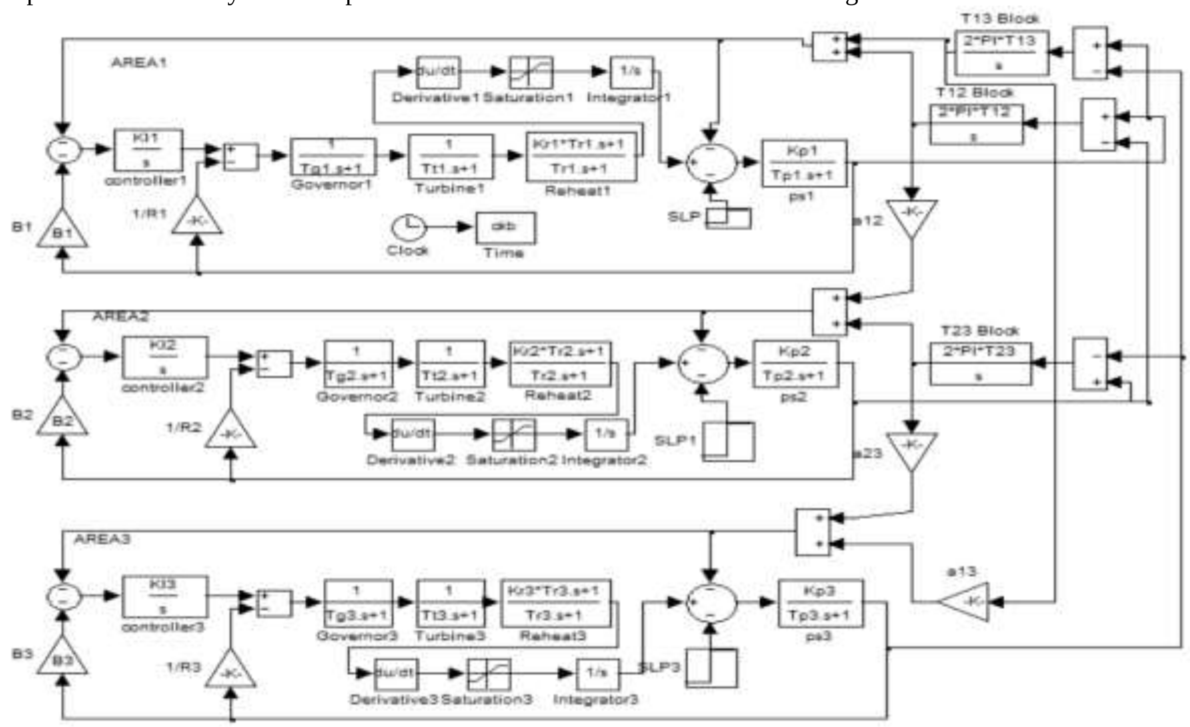

Fig.2. Transfer function model of a three area thermal system considering generation rate constraints [2]

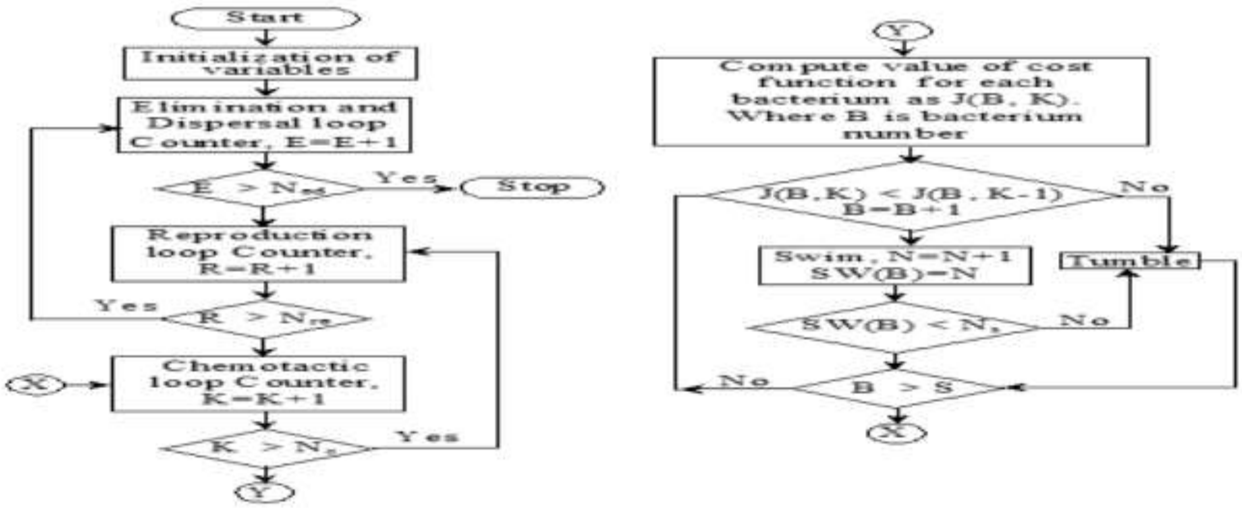

Fig.3. Flow chart of BF technique[2]

Result and Analysis

The parameter of speed regulation of two equal area is R1 = R2 = 4.231% and frequency bias parameter of B1 = B2 = β = 0.392 approximately. The response for three unequal interconnected control area for Integral and Integral-Double-Derivative controller and optimized by BF technique.

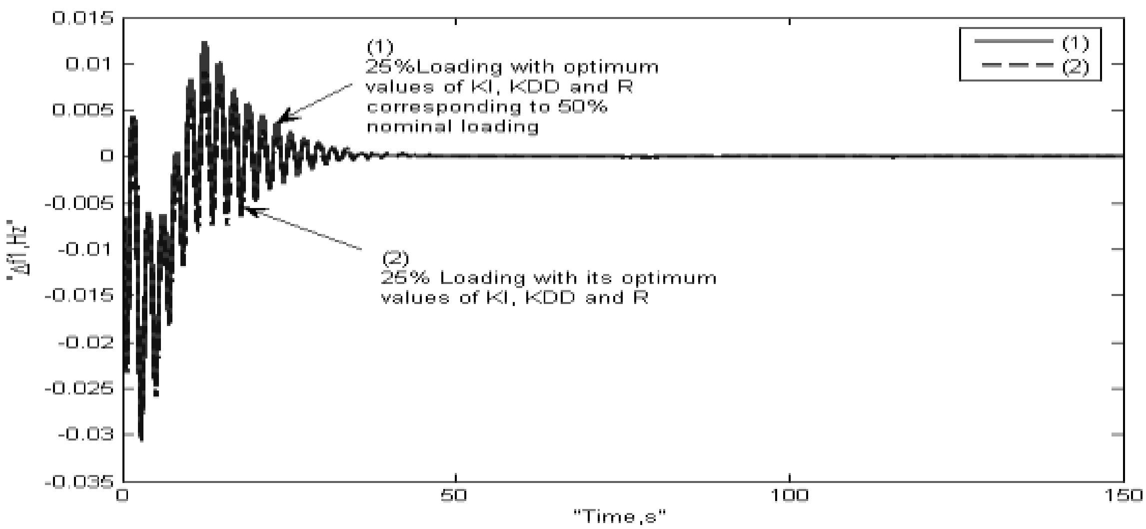

Fig. 4(a) Δf1= f(t) for 25% loading for the three unequal area system with 1% SLP in area1[2]

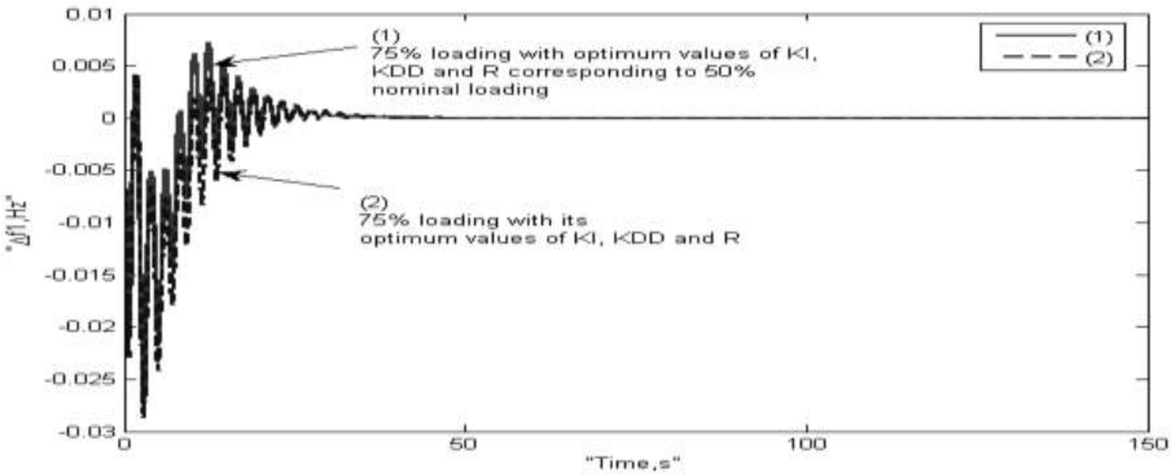

Fig. 4(b) Δf1= f(t) for 75% loading for the three unequal area system with 1% SLP in area1[2]

The optimized value of Integral controller are R1 = 8.95 (≈ 15 %), R2= 4.01 (≈ 7.5 %), R3= 3.13 (≈ 6 %), KI1 = 0.25, KI2 = 0.089, KI3 = 0.35; and for the Integral- Double Derivative controller are R1= 8.78 (≈ 15 %), R2 = 4.37 % (≈ 8 %) , R3 = 3.10 (≈ 6 %), KI1= 0.13 , KI2 = 0.09, KI3 = 0.12, KDD1= 0.05, KDD2 = 0.03 and KDD3 = 0.07. Examining the responses Δf1 = f (t), Δf2 = f(t), Δf3 = f (t) and ΔPtie1-2=f(t). It is clearly seen that Integral-Double Derivative controller gives much better performance.

B. Two area interconnected system of thermal power system maintain the balance between the total generations against system load losses. The main objective of AGC, when high frequency deviation has occurred, system collapse in order to maintain the stability, a very fast and accurate controller is needed to maintain the nominal system frequency [7]. The particle swarm optimization (PSO) technique to optimize the integral controller gains for the automatic generation control (AGC) of the interconnected two area power system [8]. Integral and proportional integral controller optimized through PSO technique and compares their response artificial intelligent controller/ PSO based controller [9].

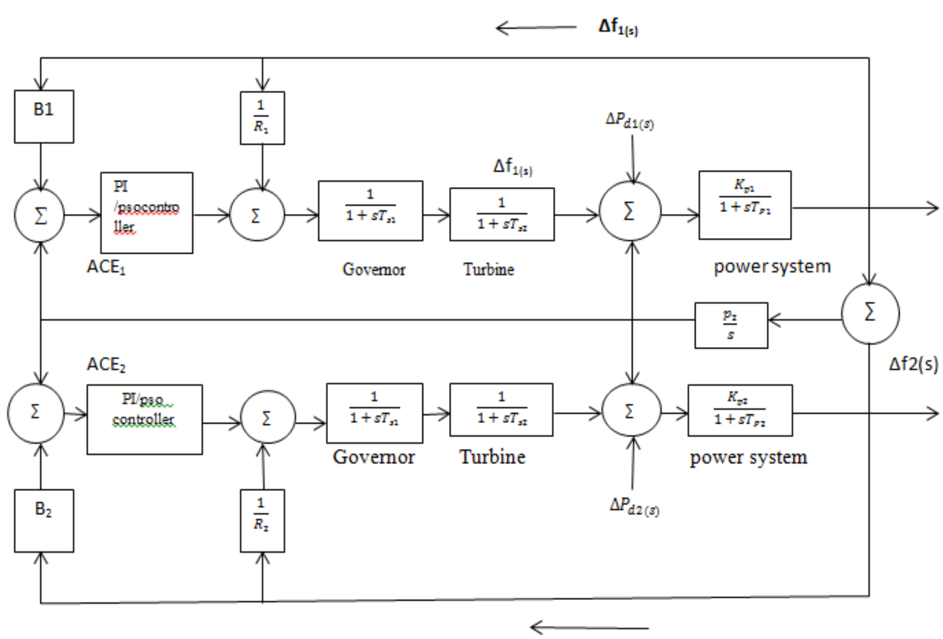

Fig.5. Linear model of two area system [7].

Two equal area system parameters b1 = b2 = b and ki1 = ki2 = ki and yhid values are optimized by using PSO technique.

Design of PSO- based Controller

Step1.The minimum and maximum gain limits of PI controllers are specified from the conventional PI controller. The initial Particle matrix of (N X 4) is generated by selecting a value with a uniform probability over the search space (g_{min}=0, g_{max}=1).

Step2.The initial Particle velocities are set to zero.

Step3. Evaluate the initial population by simulating the Load frequency Control block model with each particle row value as the PI controller gain value and calculate Performance index (ISE/ITAE) for each particle.

Step4. Initialize local minimum (P_best) for each particle.

step5. Find the best particle (g_{best}) in initial particle matrix based on the minimum performance index.

Step6. Start the iteration iter =1.

Step7. Update the velocity of the particle using the equation shown below, Velocity=C*(w*velocity+c1*r1*(Pbest-Particle)+c2*r2*((ones(N,1)*Gbest)-Particle)) Where Constriction factor C=1 Cognitive parameter c1 =1 Social parameter c2 = 4-c1 Inertia weight w=(maximum iter- iter)/maximum iter r1, r2 are the random numbers between 0 and 1.

Step8. Create new particle from the updated velocity.

Step9. If any of the new Particles violate the search space limit then choose the particle and generate new values within the particle search space.

Step10. Evaluate the performance index value for each new particle by simulating the LFC block model.

Step11. Update the best local position (p_{best}) for each particle based on the minimum value comparison between new Particle performance index and old p_{best}performance index.

step12. Update G_best Global minimum particle and its performance index. step13.Iter=iter+1

step14. If iter<= maxiter go to step 7, otherwise go to next step.

step15. Print the global best PID controller gain values and its performance index value.Performance of PSO-Based controller is better than Integral and Proportional -Integral controller.

Result and analysis

In two equal area interconnected system particle swarm optimization has successfully applied and tuned the parameter of integral and Proportional Integral Derivative controller, Also the simulation results are compared with a conventional PI controller. The result shows that the proposed PSO controller is having improved dynamic response and at the same time faster than conventional PI controller.

C. Conventional controller and PSO – Based controller use in this technique and find out better performance [10, 11].

Overview on PSO Technique

PSO is a population based EA that has many primitive benefits over other optimization techniques [12, 13]. Each particle coordinates represent a possible solution assisted with two real vectors. Each particle coordinates represent a possible solution assisted with two real vectors. And VI = [vi1, vi2, vi3...vi N] are the two vectors assisted with each particle „ i's in N-dimensional search space.

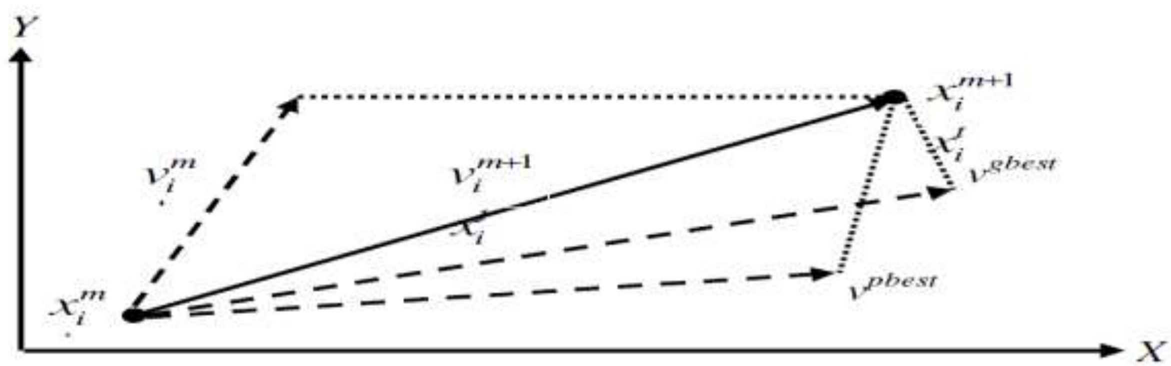

Fig.6. Concept of modification of searching point [10].

Number of particles or possible solutions of a swarm can go forward through the feasible solution place to explore optimal solutions. Each particle modifies its position based on its own best exploration, and overall experience of best particles.

This particle also considers its previous velocity vector according to the following reference equations,

 ISSN 2277 – 5528
Impact Factor- 4.015

Velocity modifications

Each particle velocity can be modified by the following equation:

$$v_i^k = \frac{1}{w} c[(c_1 rand\, x(pbest_i - s_i^k) + \qquad c_2 rand\, x(gbest_i - s_i^k)] - v_i^k \quad (1)$$

Position modifications

Positions of the particles are modified at each interval of the flying time. The position of the particle may be change or not change, depending on the solution value.

$$x_i = \quad v_i^{k+1} - x_i^{k+1} (2)$$

Where, v_i is velocity of particle, i at iteration of m.

Typical values for the inertia parameter are in the range [0.48, .98]. On the other side several different approaches using a construction factor s, which increase the algorithm's capability to converge to a better solution and the equation used to modify the particle's velocity.

$$v_i^m = \qquad \frac{1}{w}[\{c_1 r_1 x(pbest_i - \quad x_i^m) c_2 r_2 x(gbest_i - \quad x_i^m)\} - \quad v_i^{m+1} \qquad (3)$$

The PSO algorithm with constriction factor can be considered as a special case of the algorithm with inertia weight since the parameters are interacted through the Eqn[5].From investigational studies, the best approach to use with PSO as a rule of thumb is to utilize the constriction factor approach or utilize the inertia weight approach while selecting w, c1and c2 according to Eqn [5].PSO-Based controller provide better performance and dynamic response[14].

D. In deregulated environment three area interconnected system conventional controller Integral (I) and soft controllers, Fuzzy controller, Fuzzy-PID controller.

$$\frac{2}{\left|2-\varphi-\sqrt{\varphi^2-4\varphi}\right|}, c_1 + c_2 = \varphi \le 1 \qquad (4)$$

The PSO algorithm with constriction factor can be considered as a special case of the algorithm with inertia weight since the parameters are interacted through the Eqn[5].From investigational studies, the best approach to use with PSO as a rule of thumb is to utilize the constriction factor approach or utilize the inertia weight approach while selecting w, c1and c2 according to Eqn [5].PSO-Based controller provide better performance and dynamic response[14].

D. In deregulated environment three area interconnected system conventional controller Integral (I) and soft controllers, Fuzzy controller, Fuzzy-PID controller.

Fuzzy Tuned controller

The inherent features of the changing loads, difficulty and multi-variable conditions of the power system limits the conventional control techniques giving adequate solutions. Artificial intelligence based gain scheduling is another method commonly used in designing controllers for non-linear systems. Fuzzy system converts a human knowledge into mathematical formula. Therefore, fuzzy set theory based approach has developed as a complement tool to mathematical approaches for solving power system difficulties [15]. Fuzzy control is depend upon a logical system called fuzzy logic which is must closer in spirit to human thinking and natural language than classical logical systems. Nowadays fuzzy logic is used in nearly all sectors of industry and science. One of them is AGC. The fuzzy logic controller designed for the system analysis is shown in The fuzzy logic controller is consisting of four main components (1).The fuzzification, the interface engine, the rule base, and the defuzzification. The several components are present for the in depth study of the system. The fuzzifier converts the numeric/crisp value into fuzzy sets: hence this operation is called fuzzification. The core factor of the fuzzy logic controller is the interface engine, which makes all logic operations in a fuzzy logic controller. The rule base comprises of membership functions and control rules. Finally, the result of interface process is an output of the fuzzy logic controller should be a numeric/crisp value. Thus, fuzzy set is transformed into a numeric value by using the defuzzifier. This operation is called defuzzification [16].

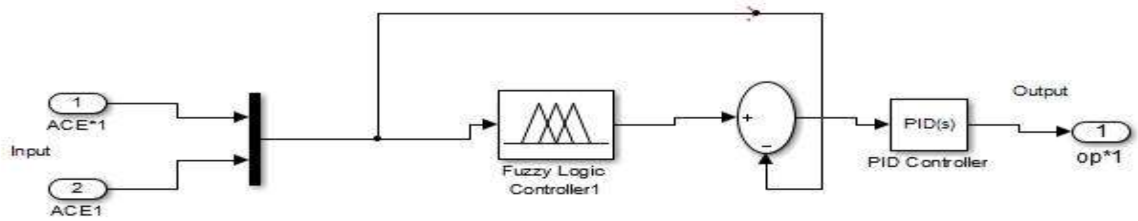

Fig.7. Fuzzy tuned controller[10].

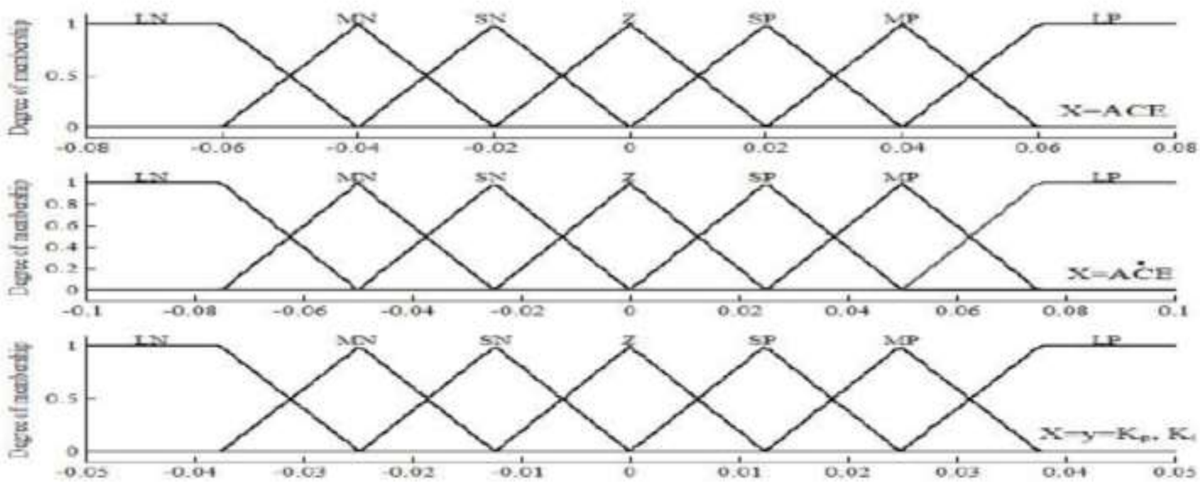

Fig.8. Waveform of logic controller[13].

The control signal,

$$U(t) = x_{py} + x_i \int y dt$$

X_p_And X_i are the proportional and the integral gains respectively and taken equal to one.

Fuzzy logic shows understanding and preference through membership functions which have different shapes. These rules are based on experiments of the process step response, error signal, and its time derivative (1). The membership functions of the fuzzy logic pi controller presented in fig comprises of three membership functions (two-inputs and one-output) (1). Respective membership function has seven memberships comprising two trapezoidal and five triangular memberships**.**

Conclusion

The efficient tuning of single input Fuzzy-PID controller structure in each area for a two-area interconnected thermal power system. Results obtained for FPID controller structure used for automatic generation control of the proposed power system tuned by PSO algorithm yields better transient performance. It is a computational intelligent based technique, more efficient and fast technique for optimization of different gains in load frequency control. MATLAB/SIMULINK is used as a simulation tool.

References

[1]Allen J. Wood, Bruce F. Wollenberg, "Power Generation, Operation and Control". Second Edition.

[2] J. Nanda, Lalit Chandra Saikia, "comparison of performances of several types of classical controller in an automatic generation control for an interconnected multi-area thermal power system. AUPEC'08,pp-022,2008.

[3] C. Concordia and L. K. Kirchmayer, "Tie-line power frequency control of electric power system: Part II," AISE Trans, III-A, vol. 73, pp. 133–146, Apr. 1954.

[4] O. I. Elgerd and C. E. Fosha, "Optimum megawatt-frequency control of multiarea electric energy systems," IEEE Trans. Power Apparat. Syst., vol. PAS-89, no. 4, pp. 556–563, Apr. 1970.

[5] C. E. Fosha and O. I. Elgerd, "The megawatt-frequency control problem-A new approach via optimal control theory", IEEE Trans. Power Apparat. Syst., vol. PAS-89, no. 4, pp. 563-577, Apr. 1970.

[6] B. K. Sahu, P.K. Mohanty, S. Panda, S.K. Kar, N. Mishra, “design and comparative performance analysis of PID Controller Automatic Voltage Regulator tuned by Many optimization Liaisons”.2012 IEEE.
[7]Jeevithavenkatachalam, Rajalaxmi. “Automatic generation control of two area interconnected power system using particle swarm optimization”. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 6, Issue 1 (May. - Jun. 2013), PP 28-36.
[8] Hussein Sheehy, Heidi Ali Shan far “Real time simulation of AGC for interconnected power system” IEEE Transactions on Power Systems, Vol. 14, No. 4, November, 2010.
[9]Pardeep Nain Assistant Professor MUIT, Hansi Haryana, India K. P. Singh Parmar Assistant Director (Technical) CAMPS, NPTI, Faridabad Haryana, India, 121003 A. K. Singh Associate Professor DCRUST, Murthal Haryana, India” Automatic Generation Control of an Interconnected Power System Before and After Deregulation”International Journal of Computer Applications (0975 – 8887) Volume 61– No.15, January 2013.
[10]NaimulHasan, Ibraheem and ShuaibFarooq, “ Real time Simulation of Automatic Generation Control for Interconnected Power System”, International Journal of Electrical Engineering and Informatics,Vol. 4, Number 1,March 2012.
[11] Aswini Kumar Patel, MrDharmendra Ku. Singh, MrBinod Kumar Sahoo, “Automatic generation control of a two unequal area thermal power system with PID controller using Differential Evolution Algorithm”. Vol. 3, Issue 4, Jul-Aug 2013, pp.2628-2645.
[12]KapilGarg*, JaspreetKaur, “Particle Swarm Optimization Based Automatic Generation Control of Two Area Interconnected Power System”, International Journal of Scientific and Research Publications, Volume 4, Issue 1, January 2014 1 ISSN 2250-3153
[13] Tridipta Kumar Pati, JyotiRanjanNayak, Binod Kumar Sahu, Sanjeeb Kumar Kar, “Automatic Generation Control of Multi-Area Thermal Power System using TLBO Algorithm Optimized Fuzzy-PID Controller” , 2015 International Conference.
[14]YogendraArya, Narender Kumar, Hitesh DuttMathur,”Automatic Generation Control in Multi Area Interconnected Power System by using HVDC Links” IJEDS(International Journal of Power Electronics and Drive System) Vol.2, No.1, March 2012, pp67-75, ISSN: 2088-8694.
[15] I.J Nagrath and D.P. Kothari, “Modern Power System Analysis” 3rd Edition, Sixteenth reprint 2009, Tata Mc-Graw Hill publication.
[16] K.Jagatheesan1, B.Anand2, V.Santhi3,Nilanjan Dey4, Amira S. Ashour5,Valentina E. Balas6, “Dynamic Performance Analysis of AGC of Multi- Area Power System Considering Proportional- Integral-Derivative Controller with Different Cost Functions”. International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – 2016.