Load Frequency Control of Two Area System Using Genetic Algorithm

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Abstract- **Today all generating area are interconnected through tie line. We require secure, economic and stable operation because in interconnected area one area is affected by change in other area. Improve power system stability we use no. of intelligence technique. In this research work, the Genetic algorithm controlling technique has been used for automatic generation control of interconnected power systems and application of Genetic algorithm to load frequency control in two area interconnected (Thermal-Thermal) power systems. The parameters of genetic algorithms are varied widely by a suitable choice of objective functions and parameters in the rule base. The Genetic algorithm is used to find the optimal values of the proportional-integral-derivation controller parameters based load frequency control. The chief aim of this work is to reduce all the fluctuations of the power system due to the disturbance and get again the frequency at prescribe value. This paper shows with tie line bias control, control parameters based on Ziegler –Nichols tuning rule and controller parameters based on GA algorithm this comparison shows that genetic algorithms give efficient output.**

Keywords- AGC, GA, LFC, PID, PSO

I. INTRODUCTION

Electrical Power system is arrangement of no. of equipment. Over, the different component and products connected to the power system are sensitive to the continuity and quality of power supply such as frequency and voltage. The frequency is inversely proportional with the load that is changing continually, and the change in real power affects the system frequency. The frequency play very significant role so when load increase and decrease all the condition require frequency must be in schedule limits. Load frequency control associated with AGC and improves system stability. So control of frequency, each generating unit is operate with speed governor and LFC control loop to regulate the frequency and real power and hold their values at the scheduled values. The leading task of LFC is to keep the frequency close to the required nominal value (50Hz) against the randomly varying active power loads, and minimize the tie-line power exchange error. Today, design a robust load frequency controller is one of the most important challenges in control and design of power system. In last decades, a various methods, control strategies and intelligent techniques have been proposed to solve load frequency control problem but, the present publications in this field are still showing a continuous interest for designing LFC systems. The most extensively used controls in the industry are based on classical PI or PID controllers. Unfortunately, classical controllers have certain problems such as: the undesirable speed overshoot and the slow response due to sudden load disturbance.

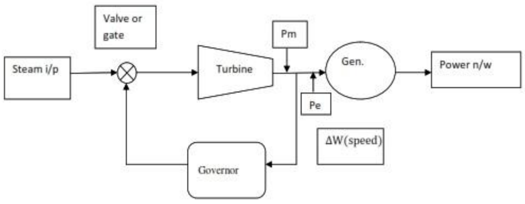

Fig.1 schematic representation of ALFC system

II. OBJECTIVE FUNCTION

The objective of work is control load frequency of two area system (thermal-thermal) using genetic algorithm. PID controller parameters are control by GA. Its parameter proportional constant Kp, integral constant K_I , and derivative constant K_d in order to minimize the error function. The error function of this work is Integral Time of Absolute Error (ITAE). The Equations is

$$J = \int_0^{t_1} (|\Delta f_1| + |\Delta f_2| + |\Delta p_{tie}|).t \qquad (1)$$

$$\Delta f_1^{min} \le \Delta f_1 \le f_1^{max} \qquad (2)$$

$$\Delta f_2^{min} \le \Delta f_2 \le f_2^{max} \qquad (3)$$

$$\Delta p_{tie}^{min} \le \Delta p_{tie} \le \Delta p_{tie}^{max} \qquad (4)$$

Where

Δf_1 = change in frequency of area-1

Δf_2 = change in frequency of area-2

Δp_{tie}= change in tie line power

III. AUTOMATIC GENERATION CONTROL

One of the most important components in the daily operation of an electrical power system is the scheduling and control of generation. This function is the primary concern of the energy control centre and largely provided by an automatic generation control (AGC) program implemented as part of the energy management system (EMS). In general, electrical power systems are interconnected to provide secure and economical operation. The interconnection is typically divided into control area with each consisting of one or more power utility companies.

The main part of power system operation and control is to maintain continuous supply of power with an acceptable quality, to all the consumers in the system. The system will be in equilibrium, when there is a balance between the power demand and the power generated. As the power in AC form has real and reactive components: the real power balance; as well as the reactive power balance is to be achieved. There are two basic control mechanisms used to achieve reactive power balance (acceptable voltage profile) and real power balance (acceptable frequency values). The former is called the automatic voltage regulator (AVR) and the latter is called the automatic load frequency control (ALFC) or automatic generation control (AGC).

The primary components to consider are the synchronous generators, the prime movers (hydraulic and steam turbines), the speed-governing system, which includes the governor and the load reference actuator (speed changer), the unit controller and the AGC system (as shown

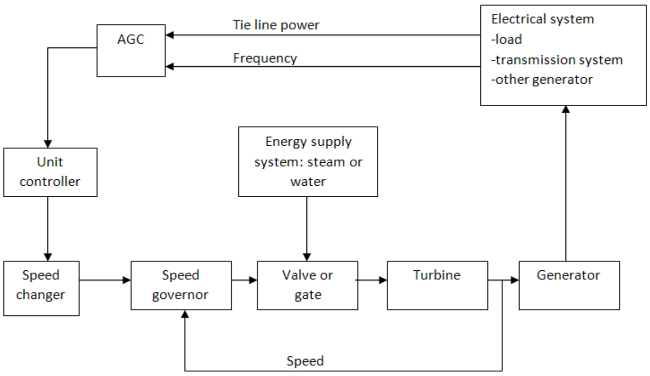

Fig.2 Basic power system control structure

The main works of AGC are

(i) To maintain the scheduled tie-line flows.

(ii) To regulate the frequency using both primary and supplementary control.

A. AGC in A Single Area System

In a single area system, there is no tie-line schedule to be maintained. Thus the function of the AGC is only to bring the frequency to the nominal value. The supplementary loop in AGC which uses the integral controller to change the reference power setting so as to change the speed set point. The controller gain K needs to be adjusted for satisfactory response (in terms of overshoot, settling time) of the system. Although each generator will be having a separate speed governor, all the generators in the control area are replaced by a single equivalent generator, and the AGC for the area corresponds to this generator.

B. AGC in A Two Area System

In an interconnected (two area) system, there will be one ALFC loop for each control area (located at the EDC of that area). They are combined as shown in Fig. 4 for the interconnected system operation. For a total change in load of ΔP_D, the steady state deviation in frequency in the two areas is given by

$$\Delta f = \Delta w_1 = \Delta w_2 = \frac{-\Delta P_D}{\beta_1+\beta_2} \qquad (5)$$

Where

$$\beta_1 = (D_1 + \frac{1}{R_1}) \qquad \text{and} \qquad \beta_2 = (D_2 + \frac{1}{R_2})$$

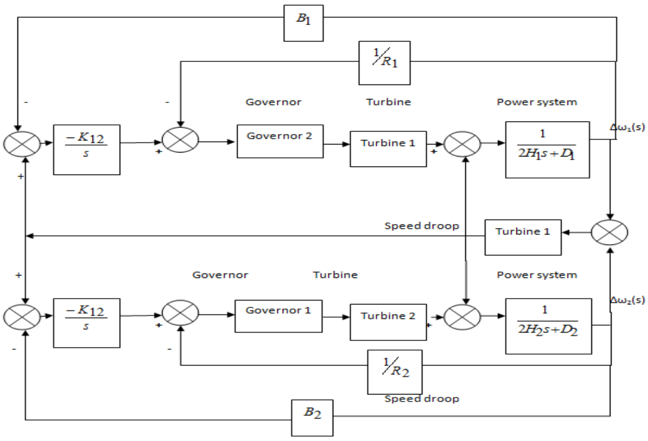

Fig.3 AGC for two-area system

C. Expression For Tie-Line Flow In A Two-Area Interconnected System

Consider a change in load ΔPD1 in area1. The steady state frequency deviation Δf is the same for both the areas. That is Δf = Δf1 = Δf2. Thus, for area1, we have

$$\Delta P_{m1} - \Delta P_{D1} - \Delta P_{12} = D_2 \Delta f \qquad (6)$$

Where, ΔP12 is the tie line power flow from area1to area2

For area2

$$\Delta Pm2 + \Delta P12 = D2\Delta f \qquad (7)$$

Frequency change

$$\Delta f = \frac{-\Delta P_{D1}}{(\frac{1}{R_1}+D_1)+(\frac{1}{R_2}+D_2)} = \frac{-\Delta P_{D1}}{\beta_1+\beta_2} \qquad (8)$$

$$\text{And} \quad \Delta P_{12} = \frac{-\Delta P_{D1}\beta_2}{\beta_1+\beta_2} \qquad (9)$$

Where

β_1(area1) and β_2(area2) are the composite frequency response characteristics.

An increase of load in area1 by ΔPD1 results in a frequency reduction in both areas and a tie-line flow of ΔP12. A positive ΔP12 is indicative of flow from area1 to area2 while a negative ΔP12 means flow from area2 to area1. Similarly, for a change in area2 load by ΔPD2, Then

$$\Delta f = \frac{-\Delta P_{D2}}{\beta_1+\beta_2} \qquad (12)$$

$$\Delta P_{12} = \Delta P_{21} = \frac{-\Delta P_{D2}\beta_2}{\beta_1+\beta_2} \qquad (13)$$

Area control error for area1

$$ACE_1 = \Delta P_{12} + \beta_1 \Delta f \quad (14)$$

Area control error for area2

$$ACE_2 = \Delta P_{21} + \beta_2 \Delta f \quad (15)$$

IV. INTELLIGENT CONTROL TECHNIQUES

Optimization is a mathematical regulation that concern the finding of minima and maxima of function, subjected to so call constraints. Today, optimization comprises a wide variety of techniques from operations research, artificial intelligence and computer science, and used to improve business processes in practically all industries. Optimization means the act of finding the best solution. Mathematical programming or optimization modeling is a branch of mathematical modeling which is concerned with finding the best solution to a problem. In further different methods have been proposed in the aim to regulate this problem. However, the difficulties in LFC are not only to design a robust controller but it also to optimize its parameters effectively for optimal solution to attain this objective, many optimization approaches are applied in LFC problem and are available such as: Genetics Algorithm (GA), Particle Swarm Optimization (PSO) technique, Bacterial Foraging Optimization (BFO), Differential Evolution Algorithm (DEA), Artificial Neural Networks (ANN), Fuzzy Logic Control (FLC) and other intelligent approaches. In this thesis, the Genetics Algorithm (GA) optimization algorithm based PID type controller is proposed as a solution to the optimal LFC problem in the aim to overcome frequency and tie line power deviation. The proposed Genetics Algorithm (GA) approach has been tested on interconnected two-area (Thermal-Thermal)power systems. The results prove that the proposed Genetics Algorithm (GA) technique has better dynamic response compared to Particle swarm optimization techniques.

A.Genetic Algorithm

A genetic algorithm is a probabilistic search technique that computationally simulates the process of biological evolution. The following flowchart gives an overview of the steps the algorithm performs.

It mimics evolution in nature by frequently altering a population of candidate solutions until an optimal solution is found. The GA evolutionary cycle starts with a randomly selected initial population. The changes to the population happen through the processes of selection based on fitness, and alteration using mutation and crossover. The application of selection and alteration leads to a population with a higher proportion of improved solutions. The evolutionary cycle carry on until an acceptable solution is found in the current generation of population, or some regulator parameter such as the number of generations is exceeded The smallest unit of a genetic algorithm is called a gene, which denotes a unit of information in the problem domain. A series of genes, recognized as a chromosome, signifies one possible solution to the problem. Each gene in the chromosome signifies one component of the solution pattern.

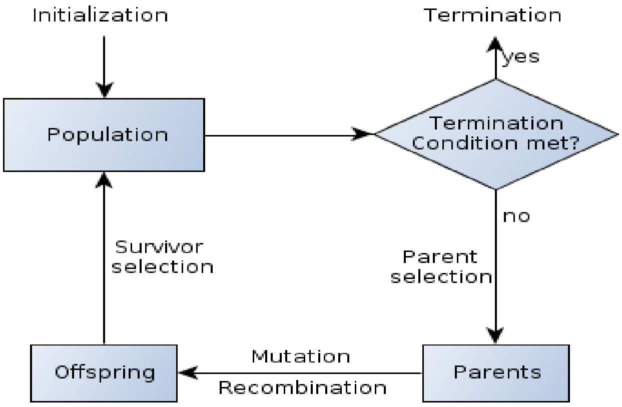

Fig. 4 Basic flow of GA

The most common form of representing a solution as a chromosome is a string of binary digits. Each bit in this string is a gene. The procedure of converting the solution from its unique form into the bit string is known as coding. The specific coding system used is application dependent. The solution bit strings are cracked to enable their evaluation using a fitness measure

(i) Selection-In biological evolution, only the fittest survive and their gene pool contributes to the creation of the succeeding generation. Selection in GA is also based on a similar process. In a common form of selection, recognized as fitness proportional selection, every chromosome’s likelihood of being selected as a decent one is proportional to its fitness value

(ii) Crossover-Crossover may be regarded as artificial mating in which chromosomes from two individuals are combined to create the chromosome for the next generation. This is carried out by splicing two chromosomes from two different solutions at a crossover point and swapping the spliced parts. The fact is that some genes with good characteristics from one chromosome may as a result combine with some good genes in the other chromosome to create a better solution represented by the new chromosome.

(iii) Mutation-Mutation is a random adjustment in the genetic composition. It is beneficial for announcing new characteristics in a population–something not achieved through crossover alone. Crossover only reorders prevailing characteristics to give new combinations.

V. SIMULATION AND RESULTS

MATLAB/SIMULINK implementation of two areas (Thermal-Thermal) load frequency control system area control error which is equal to sum of deviation in tie-line power and deviation in area frequency multiplied with frequency bias constant, together with its derivative ACE have been considered as inputs to Particle swarm optimization controller. Then find the GA Technique gives the best result. The thermal-thermal system is MATLAB implementation shown in fig. 6.1.The embedded MATLAB function only having two inputs first is direct input and second is delay input by last output. MATLAB function is only taking average of these two values so the output function Y is evaluated. That gives to the triangular function. This function gives the set value at the time of variation and gives system stability. This MATLAB implementation of two area load frequency control study in different case like tie line bias control, Ziegler-Nichols method and PID tuned GA method.

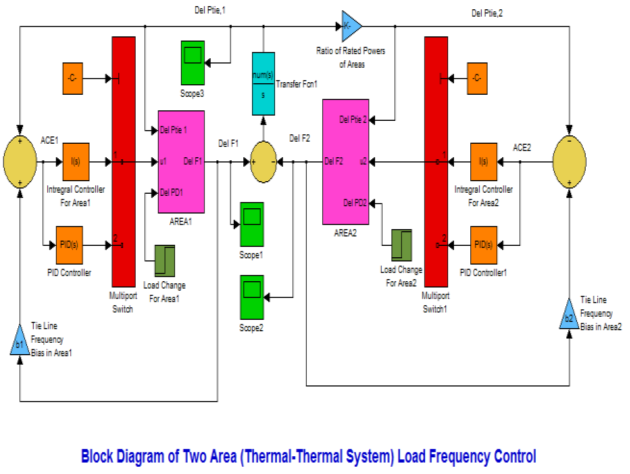

Fig.5 Simulation model LFC of two area using PID

Case-1 Frequency Deviation of area1, 2 and tie line power deviation for with tie line bias control, Ziegler Nichols, PID tuned GA method for 1% step load change in area1

Fig. 6 to 8 shows frequency deviation of area1, 2 and tie line power deviation for with tie line bias control, Ziegler Nichols, PID tuned GA method for 1% step load change in area1 .Analysis and calculates the different parameters maximum deviation, settling time. The PID tuned GA method give

A. Frequency Deviation of area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1

Fig.6 shows the frequency deviation for area1with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively. The PID tuned GA method give less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method

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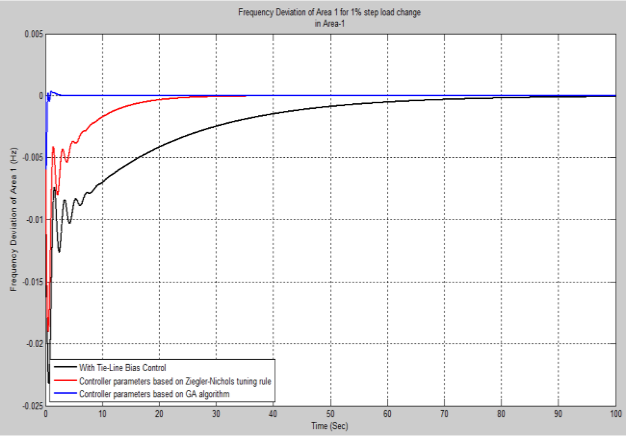


Fig. 6 Frequency Deviation of area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1

B. Frequency Deviation of area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1

Fig.7 shows the frequency deviation for area2. with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively. The PID tuned GA method get less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

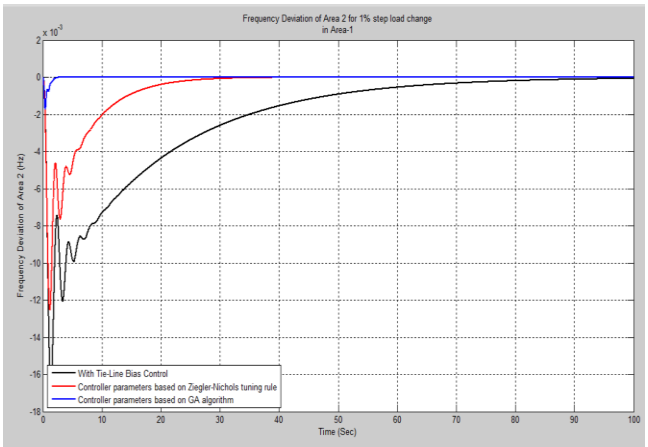


Fig. 7 Frequency Deviation of area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1

C. Tie line power Deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1

Fig.8 shows the tie line power deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively. The PID tuned GA method get less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

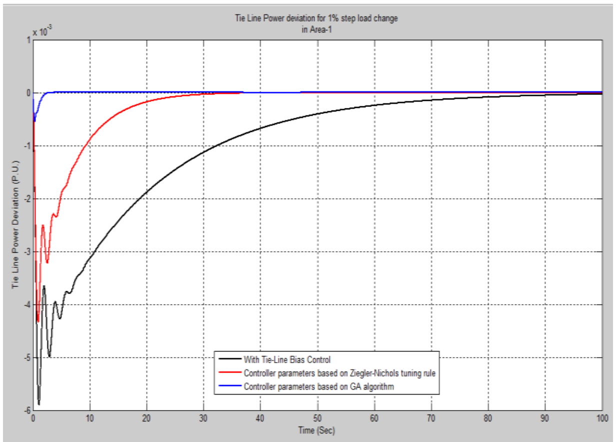


Fig.8 Tie line power Deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1

Case-2 Frequency Deviation of area1,2 and tie line power deviation for with tie line bias control, Ziegler Nichols, PID tuned GA method for 1% step load change in area2

Fig.9 to 11 shows frequency deviation of area1, 2 and tie line power deviation for with tie line bias control, Ziegler Nichols, PID tuned GA method for 1% step load change in area2.Analysis and calculates the different parameters maximum deviation, settling time. The PID tuned GA method give better result than tie line bias control and Ziegler-Nichols method.

A. Frequency Deviation of area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area2

Fig.8 shows the frequency deviation for area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively. The PID tuned GA method give less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

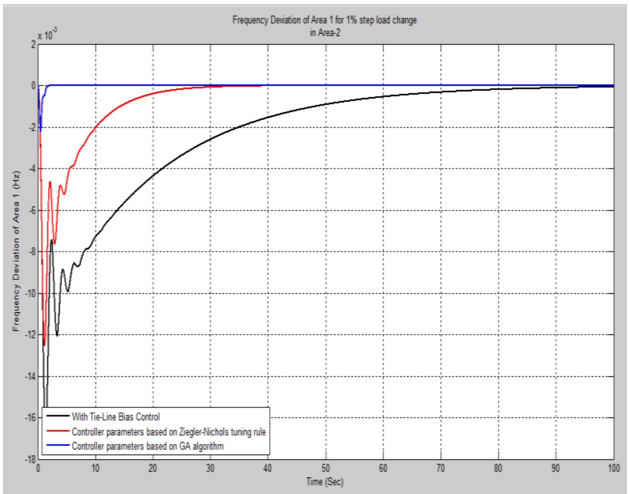


Fig.9 Frequency Deviation of area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area2

B. Frequency Deviation of area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area2

Fig.9 shows the frequency deviation for area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm The PID tuned GA method get less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method

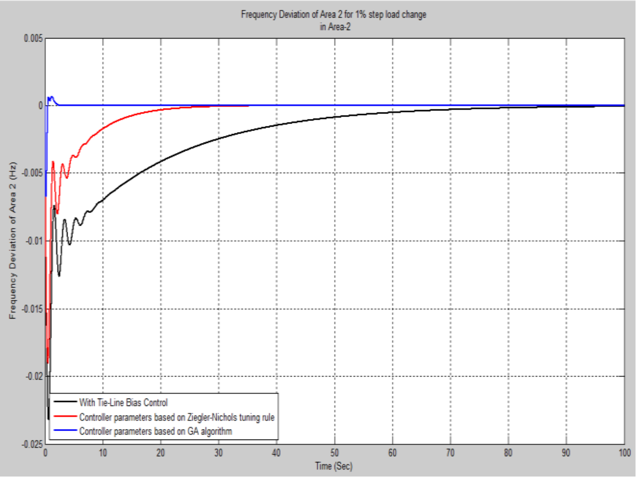


Fig.10 Frequency Deviation of area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area2

C. Tie line power Deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area2

Fig.10 shows the tie line power deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively .The PID tuned GA method get less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

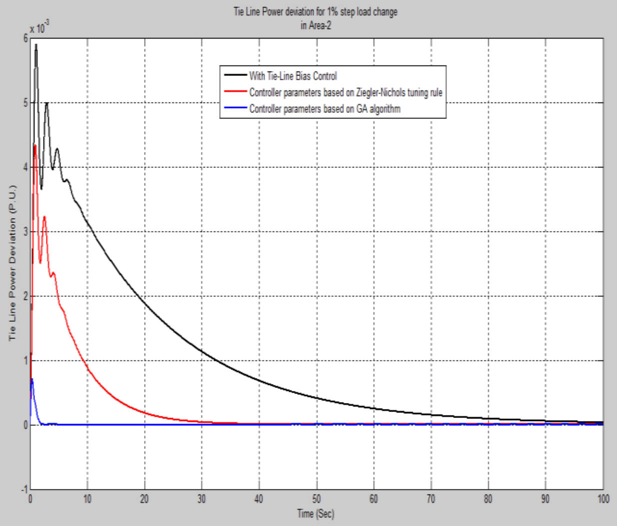


Fig.11 Tie line power Deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area2

Case-3 Frequency Deviation of area1,2 and tie line power deviation for with tie line bias control, Ziegler Nichols, PID tuned GA method for 1% step load change in area1& 2

Fig. 12 to 14 shows frequency deviation of area1, 2 and tie line power deviation for with tie line bias control, Ziegler Nichols, PID tuned GA method for 1% step load change in area1&2.Analysis and calculates the different parameters maximum deviation, settling time. The PID tuned GA method give better result than tie line bias control and Ziegler-Nichols method.

A. Frequency Deviation of area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1& 2

Fig.12 shows the frequency deviation for area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively .The PID tuned GA method give less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

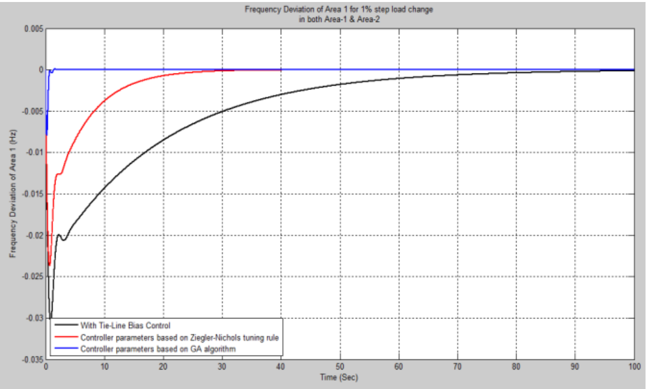


Fig 12 Frequency Deviation of area1 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1& 2

B. Frequency Deviation of area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1 &2

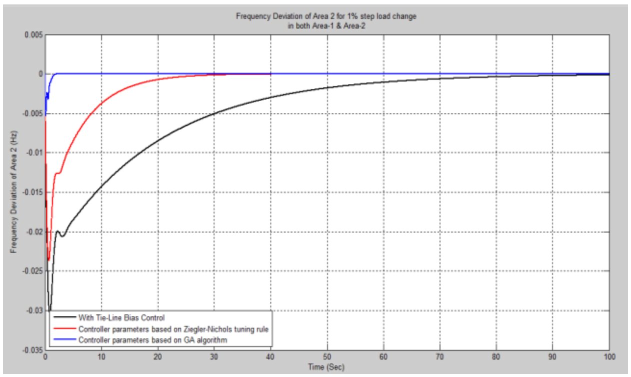


Fig.13 Frequency Deviation of area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1 &2

Fig.13 shows the frequency deviation for area2 with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm respectively .The PID tuned GA method get less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

C. Tie line power Deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1 &2

Fig.14 shows the tie line power deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm The PID tuned GA method get less settling time and maximum deviation than tie line bias control and Ziegler-Nichols method.

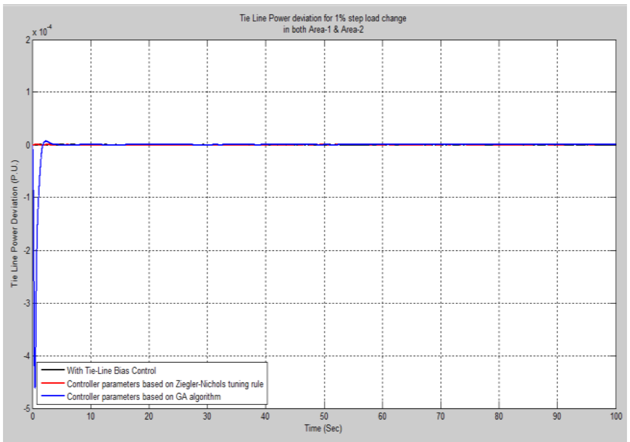


Fig.14 Tie line power Deviation with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1 &2

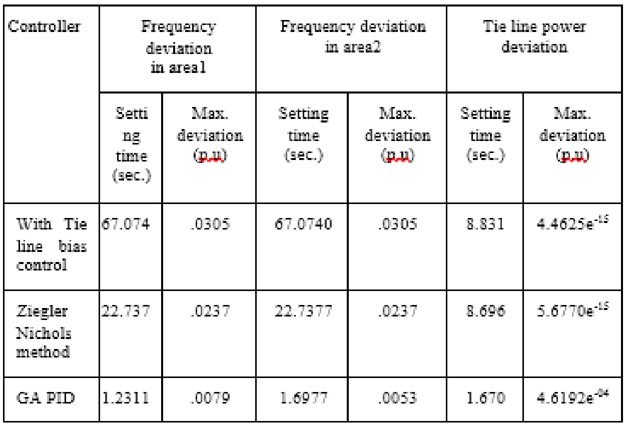
Table 1 System performance for with tie line bias control, Ziegler Nichols method, PID tuned GA method for 1% step load change in area

Controller	Frequency deviation in area1		Frequency deviation in area2		Tie line power deviation	
	Setting time (sec.)	Max. deviation (p.u)	Setting time (sec.)	Max. deviation (p.u)	Setting time (sec.)	Max. deviation (p.u)
With Tie line bias control	59.7064	.0232	65.9130	.0168	69.7650	.0059
Ziegler Nichols method	19.2707	.0190	22.9189	.0125	24.5246	.0043
GA PID	2.0877	.0059	2.3708	.0017	2.5619	$5.5040e^{-04}$

Table2. System performance for with tie line bias control, Ziegler Nichols method, PID tuned GA method for 1% step load change in area2

Controller	Frequency deviation in area1		Frequency deviation in area2		Tie line power deviation	
	Setting time	Max. deviation	Setting time	Max. deviation	Setting time	Max. deviation
With Tie line bias control	65.9130	.0168	59.7064	.0232	69.7650	.0059
Ziegler Nichols method	22.9189	.0125	19.2707	.0190	24.5246	.0043
GA PID	1.6400	.0022	1.9994	.0067	1.9665	7.1405e-04

Table3. System performance for with tie line bias control, Ziegler Nichols method, PID tuned GA algorithm for 1% step load change in area1 & 2



Controller	Frequency deviation in area1		Frequency deviation in area2		Tie line power deviation	
	Setting time (sec.)	Max. deviation (p.u)	Setting time (sec.)	Max. deviation (p.u)	Setting time (sec.)	Max. deviation (p.u)
With Tie line bias control	67.074	.0305	67.0740	.0305	8.831	$4.4625e^{-15}$
Ziegler Nichols method	22.737	.0237	22.7377	.0237	8.696	$5.6770e^{-15}$
GA PID	1.2311	.0079	1.6977	.0053	1.670	$4.6192e^{-04}$

VI. CONCLUSION

Conclusion of load frequency controller comparison with tie line bias controller, tie line bias controller tuned by GA with PID controller in both the areas, it is permissible to adopt a lower settling time and maximum deviation. The effect of tunable parameters of GA technique present in both the areas of the two area system is better. In thermal-thermal system stability can be comes faster. The optimal scaling and membership function width parameter are used in system observation give better dynamic results in case load change occurred in both areas in the system. The parameter of controller is managed by GA optimization is give more efficient output. It gives less distortion in output frequency and gives more output power in fewer time limits. Less settling time is the excursions of system state variables within acceptable limits. The system response maximum deviation and settling time of the system improve when prefer PID tuned GA technique.

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