Automatic Load Frequency Control of Two-area interconnected Thermal Reheat Power System using Genetic Algorithm with and without GRC

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Abstract: The main objective of power system operation and control is to maintain the continuity of supply with an acceptable quality and reliability. The system will be in balanced condition, when there is a balance between the power demand and the power generated. In this paper, Load Frequency Control (LFC) of single area and two-area inter-connected thermal reheat power system has been carried out by the integral controller. The system responses have been simulated in MATLAB environment. In this paper genetic algorithm is used to obtain the optimal gain of integral controller for better dynamic response of the system. In the power system, reheat and generation rate constraints (GRC) are considered. The response with GRC is compared with the analysis done without the Generation Rate Constraint.

Keyword: Load Frequency Control (LFC), Automatic Generation Control (AGC),Two area power system, Genetic algorithm (GA),Generation Rate Constraint (GRC),Area control error(ACE) and Integral square error(ISR)

I. Introduction:

A Single area power system consists of a governor, a turbine and a generator with feedback of regulation constant. The system includes step load change input to the generator. The main objectives of the Load Frequency Control are to maintain uniform frequency, to divide the load between generators and to control the tie line interchange between the power systems. A simple block diagram of a single area power system with the integral controller is shown in fig.1. The integral term adds a pole at origin resulting in reducing the steady-state error. A two-area re-heat type thermal system consists of two single areas connected through a power line called the tie-line as shown in fig 2. Each area feeds its user pool and tie-line allows the electric power to flow between areas. Since both areas are tied together, a load disturbance in one area affects the output frequencies of both areas as well as the power flow on the tie-line [4]. In the power system, reheat and generation rate constraints (GRC) are considered. The Generation rate constraint (GRC) is realized by differentiating outputs from both the power sources, thereafter a saturation limiter is used to decide the upper and lower limit of the rate [1]. The signal is further integrated to get back to the original signal. GRC for the k_{th} subsystem is 0.0005 p.u. MW/s.

A step load perturbation of 1% of nominal loading has been considered in Area-1. The effect on frequency is observed on both areas. The gains of both areas are optimized using Genetic Algorithm technique to have the minimum frequency deviation.

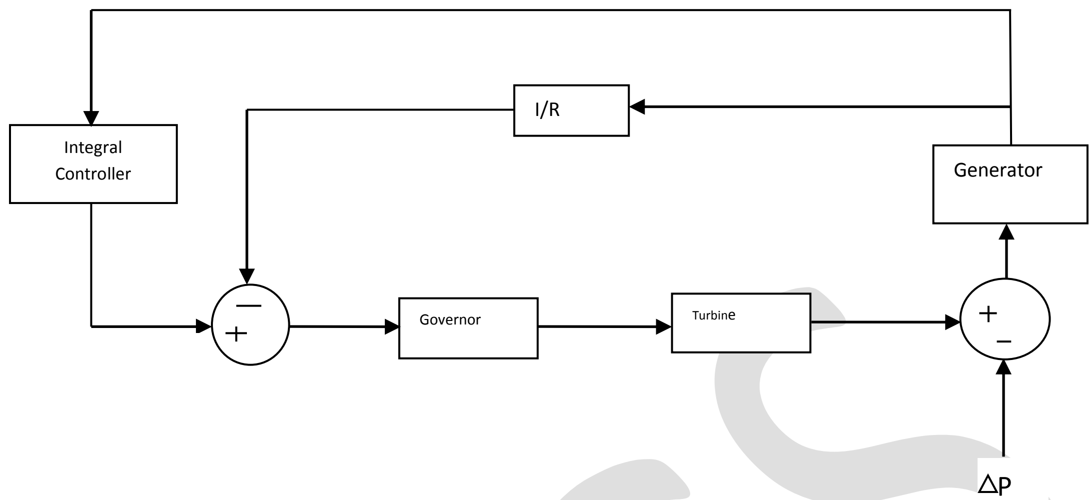

Figure.1 A single Area Power System with the integral controller.

Table-1 Nominal parameters of thermal system

Nominal parameters	Value
Rating of each area	2000MW
Base Power	2000MVA
R1=R2	=2.4Hz/p.u.MW
B1=B2	=.425puMW/Hz
f	=60 Hz
ΔP_{d1}	=0.01puMW/Hz
Tg1=Tg2	= 0.08s
Tr1=Tr2	= 10s
Kr1=Kr2	= 0.5
Tt1=Tt2	= 0.3
Kp1=Kp2	= 120Hz/p.u. MW
Tp1=Tp2	= 20s
A	= 0.5

II. System Description of two area interconnected power system

In a two-area reheat thermal system there are two single areas connected through a tie line as shown in fig 2. Each area feeds supply to its users and tie-line allows the electric power to flow between areas [2]. Since both the areas are tied together, therefore a load disturbance in one area affects the output frequencies of both areas as well as the power flow on the tie-line [4]. In figure-2, reheat and generation rate constraints (GRC) are considered. Transfer function for turbine and governor isgiven as follows:

$$T.F._{Turbine} = \frac{1}{1+sT_t}$$

$$T.F._{Governer} = \frac{1}{1+sT_g}$$

Where:

Tt: Turbine Time constant

Tg: Governor Time constant

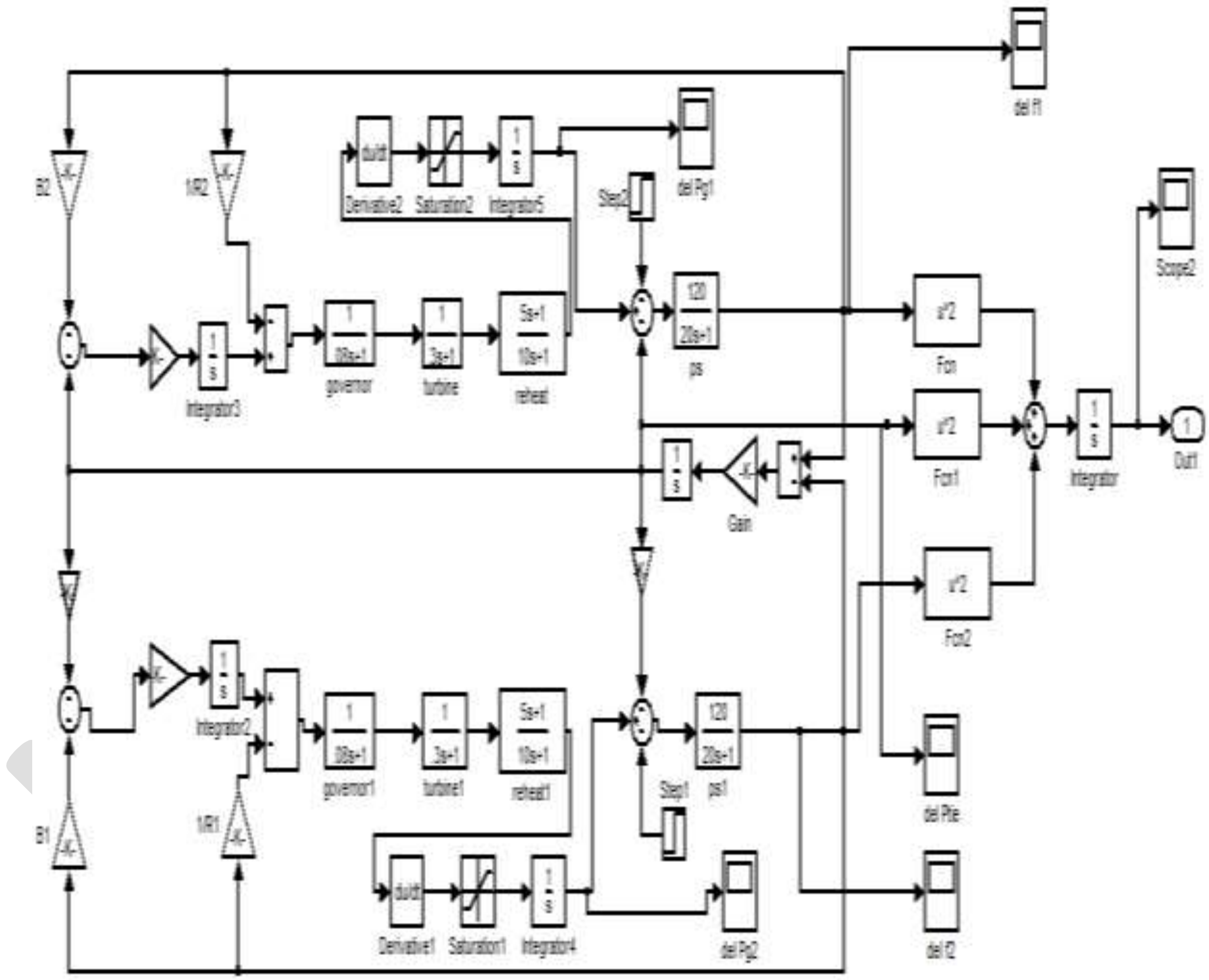

Figure- 2: Simulation Diagram Of LFC Of Two Area Power System With Proposed GA Based Integral Controller with GRC.

III. Genetic Algorithm

A Genetic Algorithm is a search technique that is used in computing to find exact or appropriate solutions to optimization and search problems by using natural operators, Genetic Algorithms can be applied to process controllers, for their optimization. They operate on a population of current approximations [3]. The individuals initially drawn at random, from which improvement is obtained. Individuals are encoded as strings (chromosomes) which are constructed over some particular alphabet, for example the binary alphabet {0, 1}, so that chromosomes values are uniquely mapped onto the decision variable domain. When the decision variable domain representation of the current population is calculated, according to the objective function the individual performance is assumed, which characterizes the problem to be solved. It is also possible to use the variable parameters directly to represent the chromosomes in the Genetic algorithms (GA) solution. At the reproduction stage, a fitness value is derived from the raw individual performance measure which is given by the objective function that is used to bias the selection process. Genetic operators can be divided into three main categories, reproduction, cross over and mutation.

1. Reproduction: The reproduction operator selects the fittest individuals in the current population that is to be used in generating the next population.

2. Cross over: The cross over operator causes pairs, or larger groups of individuals to exchange genetic information with one another.

3. Mutation: The mutation operator causes individual genetic representations to be changed according to some probabilistic rule.

IV. Formation of objective function

In the present study the objective function (integral square error ISE) is formulated as the minimization of:

$$\text{ISE} = \int \left(\Delta f 1^2 + \Delta f\, 2^2 + \Delta Ptie^2 \right)$$

Genetic Algorithms can be applied to process controllers, for their optimization. In this thesis we use the concept of Genetic Algorithm as an optimization tool. A real coded GA can be considered as an appropriate method for reaching optimal gains with fast response to system.

Considering "y" as output vector we can assume that:

$$y = \left[ACE_1 \quad ACE_2 \right]^T$$

Where ACEi is Area Control Error signal due to step type load disturbance can be calculated as:

$$ACE_i = \Delta P_{tie,i} + B_i \Delta F_i$$

In designing the controller, cost function can be assumed as minimization of "Integral of Square Error (ISE)" for step response of load deviation:

$$ISE = \int \left(ACE_i \right)^2 .dt$$

Practical cases show that "ISE" function will cause more minimization in overshoot and cause fast response with shorter settling time and consider this cost function as objective function.

$$F_{\cos t} = \int_0^t ACE^2{}_i .dt \qquad , For \quad i = 1,2 \ldots$$

In GA-consider the cost function- a fitness function is considered for each string of values, and in next stage initial population will be chosen in a way that we can use the probability of roulette.The fitness function for creating the initial population can be written as:

$$F_{Fitness} = \frac{1}{1 + F_{cost}}$$

V. Steps for Genetic Algorithm Programming using MATLAB

Parameters for Genetic algorithm

parameter	size
Population size	40
Chromosome length	14
Max Iterations	30
Elitism Probability	0.10
Cross over Probability	0.9
Mutation Probability	.001
No. of control variables	2

a. Algorithm

Step-1 Data initialization

Step-2 Set limits for gain K

Min lt [0 0]

Max lt [1 1]

Step-3 Create random initial population of 0's and 1's.

Step-4 Start the iteration from 1 to max no. of iterations.

(a) Decode the population which is constructed over some particular alphabet i.e. (0 and 1), into integer.

(b) Compute control variables.

(c) Run the Simulink model.

(d) Define the fitness function.

(e) Evaluate the fitness of each individual in the population, and arrange them by applying sorting based on fitness value by using bubble sort.

(f) Create a new population by repeating following steps until the new population is complete.

(i) First the best fit chromosomes are copies directly to the new population using elitism criteria.

(ii) Select two parent chromosomes from a population according to their fitness.

(iii) Generate offspring using cross over operator. Generate a random number and compare it with cross over probability Pc. If random number is less then Pc cross over operation is performed, otherwise no cross over is performed and parent individuals are returned.

(iv) If crossover operation is called, a crossing point is selected between 1 and chromosome length.The crossing point is selected in the function round which returns an integer between lower and upper limits that is used for creating offspring.

(g) Swap the generated offspring to parent.

(h) Use mutation operator. Mutation alters one individual parent to produce a single new individual child.

(i) Select a random number between0 to 1 and compare with mutation probability Pm

(ii) If it is less then Pm, mutation operation is called. And at the mutating point, the bit is altered from 1 to 0 or 0 to 1.

(iii) Else bit is kept unchanged.

(i) Place new offspring in the new population. Use new generated population for next iteration.

(j) If the end condition is satisfied, stop, and return the best solution in current population.

Step-5 Go to Step -4.

Step-6 When iterations > max Iterations then print 'problem is not converged in max iterations'

Step-7 Print gain ki1 and ki2

Step-8 Print total error and plot the error.

VI. Flow Chart

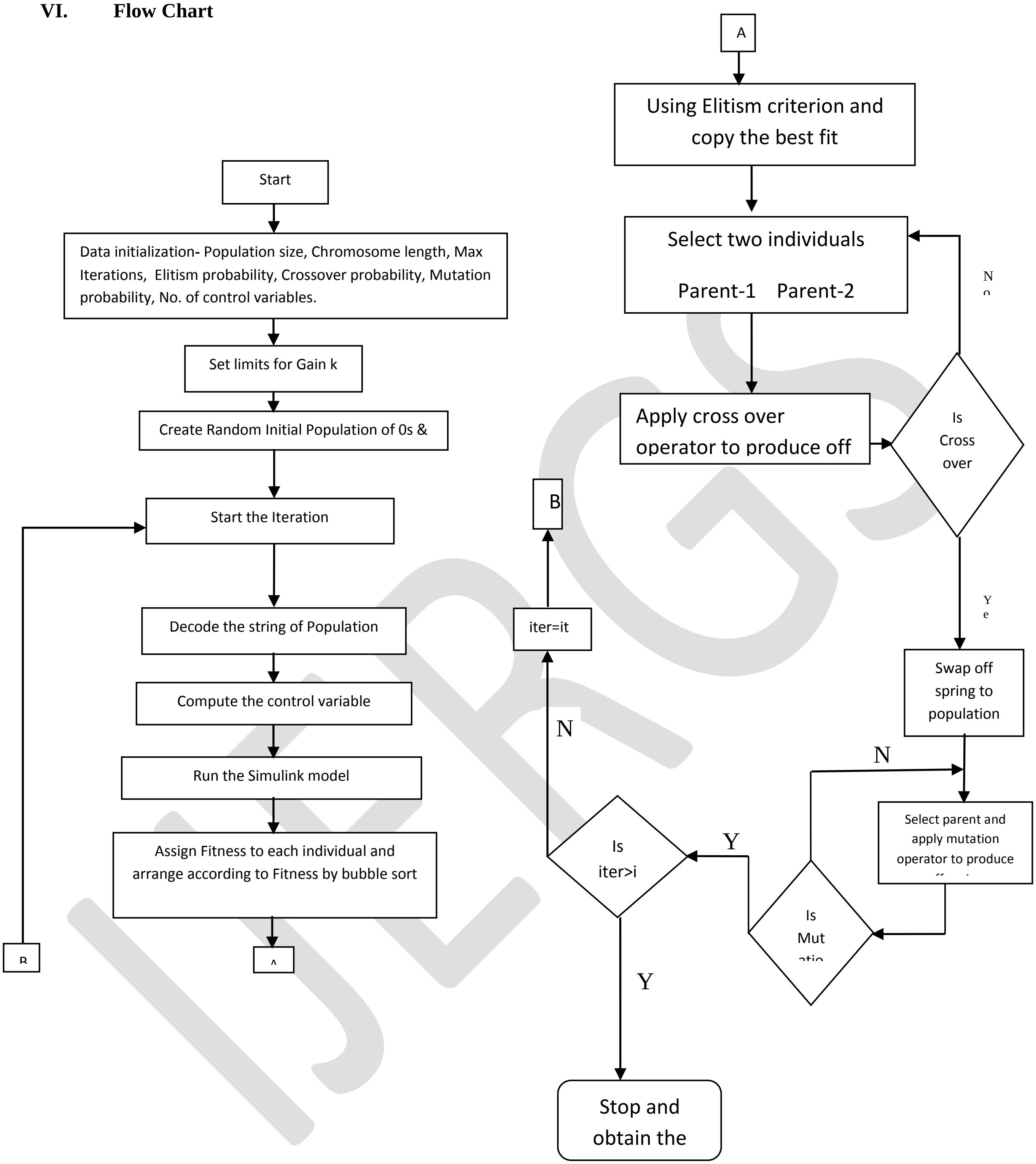

Figure 3 - Flow chart for Genetic Algorithm

VII. Simulation Results and Analysis

A two area thermal reheat power system, by using the integral controller that is tuned by Genetic Algorithm is shown in figure-2. The optimal controller gain values for the two areas obtained as shown in Table 2.

Table 2. Optimized values of system variables using Genetic Algorithm technique.

Interconnected Areas	Optimum Parameters	Controller & system parameters optimized by G.A.
Thermal power system -I	K_{i1} B_1 R_1	0.273438 0.425 2.4
Thermal power system -II	K_{i2} B_2 R_2	0.210938 0.425 2.4

Figure 4: Frequency deviation in area 1 with 1% step load perturbation in area-1 of a two area interconnected thermal reheat power systems using Integral controller tuned conventionally, k_{i1}= .02810 and k_{i2} = .02035, without GRC.

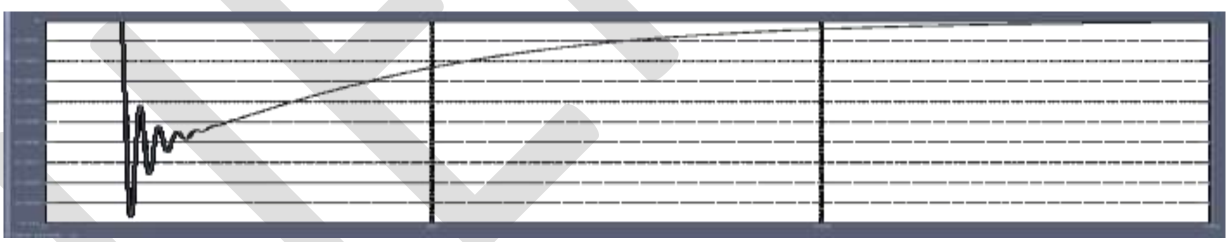

Figure 5: Tie - line power deviation with 1% step load perturbation in area-1 using Integral controller tuned conventionally, without GRC.

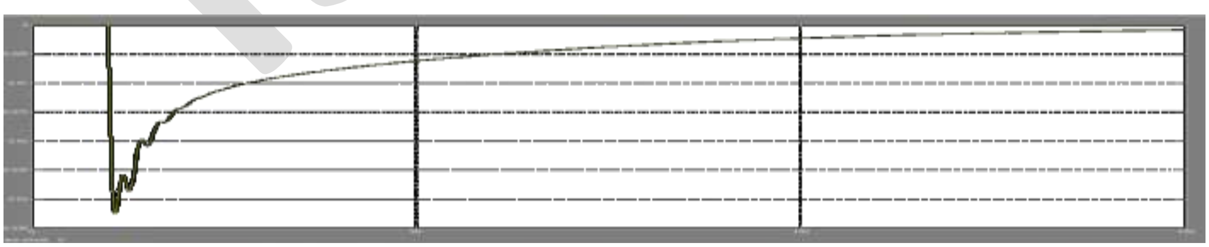

Figure 6: Frequency deviation in area 2 with 1% step load perturbation in area-2 using Integral controller tuned conventionally, k_{i1}= .02810 and k_{i2} = .02035, without GRC.

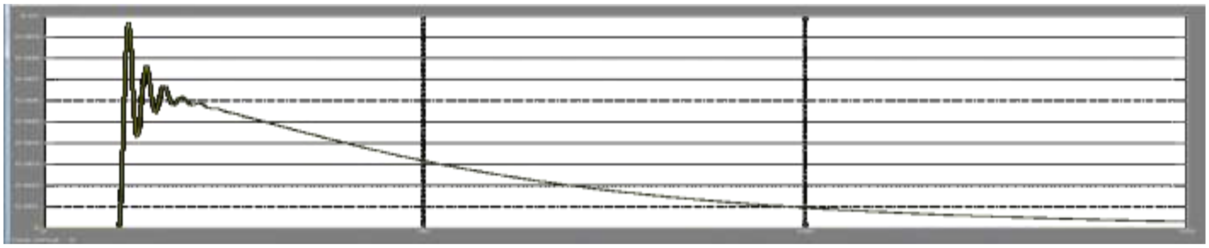

Figure 7: Tie - line power deviation with 1% step load change in area 2 with integral controller tuned conventionally without GRC.

Figure 8: Frequency deviation in area 1 of a two area interconnected thermal reheat power systems without and with GRC for 0.01 p.u.MW step load change in area 1, using Integral controller tuned by genetic algorithm.

Figure 9: Frequency deviation in area 2 without and with GRC for 0.01 p.u.MW step load change in area 1, using Integral controller tuned by genetic algorithm.

Figure 10: Frequency deviation in area 1 without and with GRC for 0.01 p.u.MW step load change in area 2, using Integral controller tuned by genetic algorithm.

Figure 11: Frequency deviation in area 2 without and with GRC for 0.01 p.u.MW step load change in area 2, using Integral controller tuned by genetic algorithm.

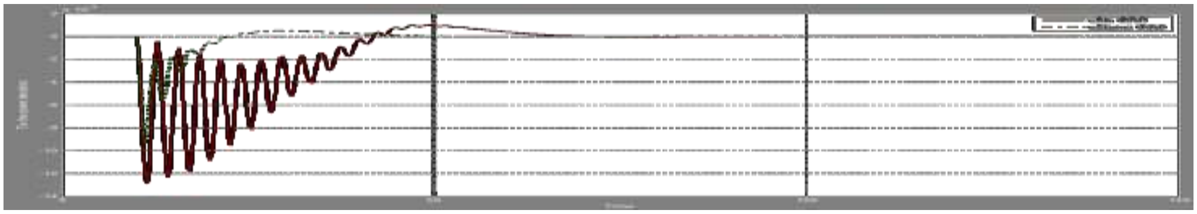

Figure 12: Tie - line power deviation with and without GRC for 0.01 p.u.MW step load change in area 1 with integral controller tuned by Genetic Algorithm.

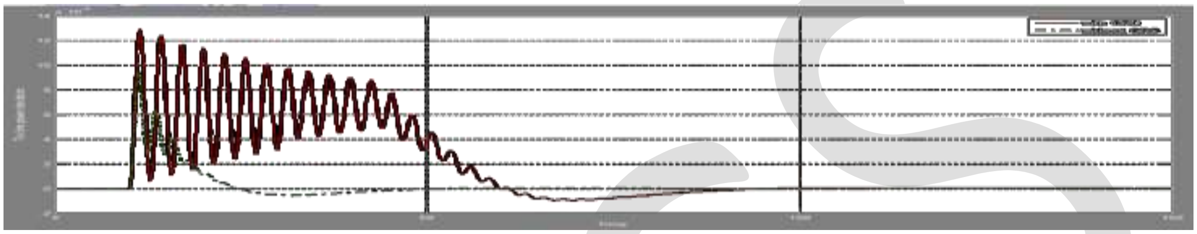

Figure 13: Tie - line power deviation with and without GRC for 0.01 p.u.MW step load change in area 2 with integral controller tuned by Genetic Algorithm.

Figure 14: Objective function (Integral square error), for 1% step load change in area-1 by Genetic Algorithm method with and without GRC

Figure 15: Objective function (Integral square error), for 1% step load change in area-2 by Genetic Algorithm method with and without GRC.

Figure-16: The performance index variation using Genetic Algorithm method.

VIII. Dynamic Response Analysis

When there is a change in an electrical load, the turbine-generator rotor accelerates or decelerates, and frequency undergoes a transient disturbance. The controller should not allow transient oscillations and trips the under-frequency relay connected in the system. Oscillations, settling time and overshoot are inter-related, and if there is a change in one parameter will affect the other parameter. Hence, the designed controller must be efficient for selecting the optimum gains to achieve better results. *R* is the speed regulation characteristic of the governor and value of R determines the slope of the governor characteristics and the change on the output for a given change in frequency. The speed governor system should be operated within the restricted control range of feedback gains due to system instability. Therefore, higher value of step load change P_d for a small R value will produce oscillations into the system. And with higher value of R, the oscillations of the system responses increase largely and settling time also increases. Hence value of R selected accordingly to obtain optimum results in terms of settling time & oscillations. If we increase the step load perturbations, then it is seen that due to increase of step load perturbation, i.e $\Delta P_{d1}>0.01$ and $\Delta P_{d2}>0$; the settling time for each of the controllers increase rapidly, which results much more oscillation. Therefore, the frequency response at small load change $\Delta P_{d1}=0.01$ gives better response.

IX. Conclusion

Load frequency control of interconnected thermal reheat power system has been discussed in this paper by using the integral controller that is tuned by Genetic Algorithm, and optimum value of gain is obtained. The Integral controller is effective for controlling this frequency change along with suitable frequency bias feedback gain (B_i) and governor speed regulation parameter (R_i). The simulation studies on the systems have been done in MATLAB/SIMULINK, which shows that the Integral controller is effective for minimizing the frequency deviation, when GRC is taken into consideration. Further, the Genetic Algorithmtechnique used for optimization of K_i, B_i and R_i is very efficient and powerful computationally intelligent technique.

Nomenclature

R_1 ,R_2 Governor speed-regulation parameter of area 1 and area 2 (Hz/p.u. MW).

B_1 ,B_2 Frequency bias of area 1 and area 2.

Δf_1 , Δf_2 Frequency deviation of area 1 and area 2

$\Delta P_{tie,i}$ Tie Line Power Deviation in Two Areas Systems

ACE Area control error

ISE Integral square error

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