Effects of Super Conducting Magnetic Energy Storage Device and Redox Flow Battery in a Genetic Algorithm Based Load Frequency Controller

A. Adhithan, K. R. Venkatesan, J. Baskaran

Abstract- **The main objective of Load Frequency Control (LFC) is to regulate the power output of the electric generator within an area in response to changes in system frequency and tie-line loading. Thus the LFC helps in maintaining the scheduled system frequency and tie-line power interchange with the other areas within the prescribed limits. Most LFCs are primarily composed of an integral controller. The integrator gain is set to a level that the compromises between fast transient recovery and low overshoot in the dynamic response of the overall system. This type of controller is slow and does not allow the controller designer to take into account possible changes in operating condition and non-linearity's in the generator unit. This paper shows the control of load frequency in a two area power system with PI controller, incorporating of Super Conducting Magnetic Energy Storage Device (SMES) and Battery Energy System (BES) such as Redox Flow Battery (RFB) for the improvement of Load Frequency Control of a two area interconnected power system using Genetic Algorithm (GA).**

Index Terms **- Load Frequency Control -Genetic Algorithm- SMES, RFB**

I. INTRODUCTION

Load Frequency Control (LFC) problem occurs due to sudden small load perturbations which continuously disturb the normal operation of a power system. The modern power systems with industrial and commercial loads need to operate at constant frequency with reliable power. The goals of the LFC are to maintain zero steady state errors in a multi area interconnected power system.[1].

LFC is a very important issue in power system with an increasing demand for electric power and more complicated .Therefore the objective of LFC of a power system is to maintain the frequency of each area and in interconnected system within specified tolerance by adjusting the new outputs of LFC generators so as to accommodate fluctuating load demand. In general LFC systems are designed with Proportional- Integral (PI) controllers. However, since the "I" control parameters are usually tuned; it is incapable of obtaining good dynamic performance for various load and system changes. In this study, Genetic Algorithm (GA) is used to determine the gain of the PID controller. In the integral controller, if the integral gain is very high, undesirable and unacceptable large overshoots will occur. However, adjusting the maximum and minimum values of proportional gain (kp) and integral gain (ki) respectively, the outputs of the system (voltage, frequency) could be improved. In this simulation study, two area power system with two different parameters are chosen and load frequency control of this system is made based on PID controller.

I. PROBLEM FORMULATION

In order to keep the power system in normal operating state, a number of controllers are used in practice. As the demand deviates from its normal operating value the system state changes. Different types of controllers based on classical linear control theory have been developed in the past [5]. Because of the inherent nonlinearities in system components and synchronous machines, most load frequency controllers are primarily composed of an integral controller. The integrator gain is set to a level that compromise between fast transient recovery and low overshoot in the dynamic response of the overall system. This type of controller is slow and does not allow the controller designer to take into account possible non-linearity in the generator unit, so the PID controller will be used for the stabilization of the frequency in the load frequency control problems. The main objectives of LFC in order to regulate the power output of the electric generator within a prescribed area in response to changes in system frequency, tie line loading so as to maintain the scheduled system frequency and interchange with the other areas within the prescribed limits. The effectiveness of LFC is judged in terms of Area Control Errors (ACE), the system output is given by

$$ACEi= \Delta Ptie,i + bi\ \Delta fi \qquad (1)$$

ACEi is area i control error, bi is area i frequency bias constant, delfi is area i frequency change, ΔPtie,i is the change in tie-line power.

II. SUPER CONDUCTING MAGNETIC ENERGY STORAGE(SMES) UNIT

Fast acting energy storage devices can effectively damp electromechanical oscillations in a power system, because they provide storage capacity in addition to the kinetic energy of the generator rotor, which can share the sudden changes in power requirement. The present paper shows the effectiveness of small sized magnetic energy storage (MES) units (both superconducting and normal loss types) for this application and suggests means of best utilization of the small energy storage capacity in such units to improve the load frequency dynamics of large power areas.[5]

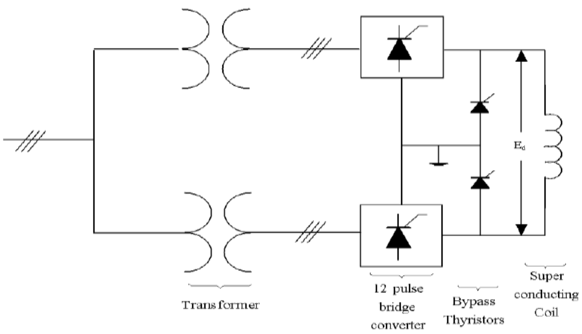

Fig.1 SMES unit: circuit point of view

The schematic diagram in Fig. 5.1 shows the configuration of a thyristor controlled SMES unit . Control of the converter firing angle provides the DC voltage Ed appearing across the inductor to be continuously varied between a wide range of positive and negative values. The inductor is initially charged to its rated current Id0 by applying a low positive voltage. Once the current reaches the rated value, it is maintained constant by reducing the voltage across the inductor to zero since the coil is superconducting. The inductor current deviation is used as negative feedback signal in SMES control loop. So, if the load demand changes suddenly, the negative feedback provides the prompt restoration of current. The inductor current must be restored to its nominal value quickly after a system disturbance so that it can respond to the next load perturbation immediately. The block diagram representation of SMES incorporating the negative inductor current deviation feedback is shown in fig 2. Thus the dynamic equations for the inductor voltage deviation and current deviation of the smes unit are

$$\Delta E_d(s) = \frac{1}{1+sT_{DC}}[K_{SMES}ACE_1(s) - K_{id}\Delta I_d(s)] \qquad (2)$$

and

$$\Delta I_d(s) = \frac{\Delta E_d(s)}{sL} \qquad (3)$$

Where ACE1 is area control error of area 1

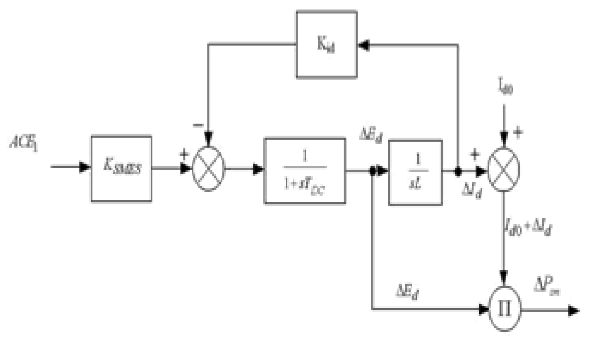

Fig.2 SMES block diagram with inductor current deviation feedback

The detailed small perturbation transfer function block diagram of the interconnected thermal power system with SMES in area 1 with the tie-line is shown in fig 3.

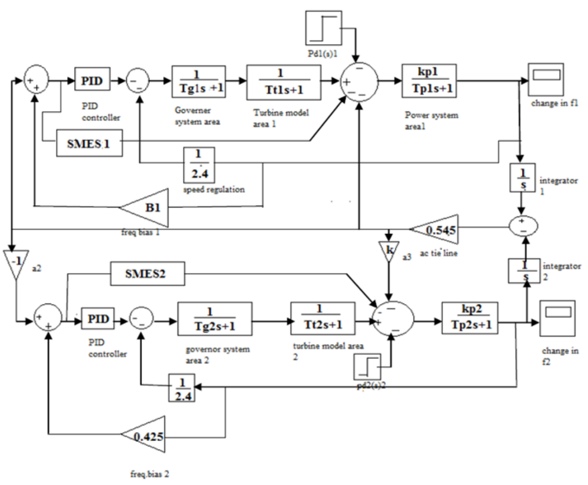

Fig 3. Small perturbation transfer function block diagram of the interconnected thermal power system with SMES

III. REDOX FLOW BATTERY (RFB) UNIT

The rechargeable batteries such as redox flow which are not aged by a frequent charging and discharging have a quick response and outstanding function during overload. The batteries efficiency increased when the cycle period of charging and discharging became shorter . In addition to levelling load, the batteries are advantageous for the secondary control of the power system and maintain a power quality of distributed power resource. The RF batteries are capable of very fast response [8] and so hunting due to a delay in response will not occur. For this reason the ACE is used as the command value for the RFB in controlling the output response in the LFC problem.The RFB include Load Frequency Control which gives the excellent short time overload output.

The effect of generation control and absorption of fluctuation needed for power quality maintenance are expected in the present power market scenario. RF batteries are capable of very fast response and , therefore, hunting due to a delay in response does not occur. For this reason, the ACE is used directly as the command value for LFC to control the output of RF batteries as shown in the below figure 4.

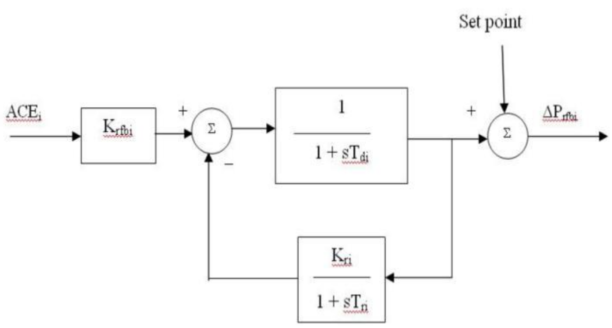

Fig.4 Redox Flow Battery system model

The detailed small perturbation transfer function block diagram of the interconnected thermal power system with RFB in area 1 with the tie-line is shown in fig 5.

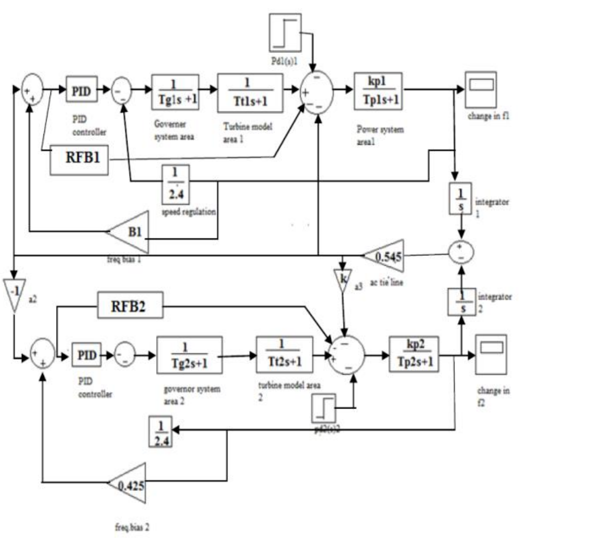

Fig 5. Small perturbation transfer function block diagram of the interconnected thermal power system with RFB

IV. GENETIC ALGORITHM BASED CONTROLLERS

Genetic Algorithms (GA.s) are a stochastic global search method [19, 20] that mimics the process of natural evolution. It is one of the methods used for optimization. John Holland formally introduced this method in the United States in the 1970 at the University of Michigan. The continuing performance improvement of computational systems has made them attractive for some types of optimization. The genetic algorithm starts with no knowledge of the correct solution and depends entirely on responses from its environment and evolution operators such as reproduction, crossover and mutation to arrive at the best solution. By starting at several independent points and searching in parallel, the algorithm avoids local minima and converging to sub optimal solutions. In this way, GAs have been shown to be capable of locating high performance areas in complex domains without experiencing the difficulties associated with high dimensionality, as may occur with gradient decent techniques or methods that rely on derivative information. The steps involved in creating and implementing a genetic algorithm:

a)Generate an initial, random population of individuals for a fixed size.

b)Evaluate their fitness.

c)Select the fittest members of the population.

d)Reproduce using a probabilistic method (e.g., roulette wheel).

e)Implement crossover operation on the reproduced chromosomes

f)(choosing probabilistically both the crossover site and the mates.)

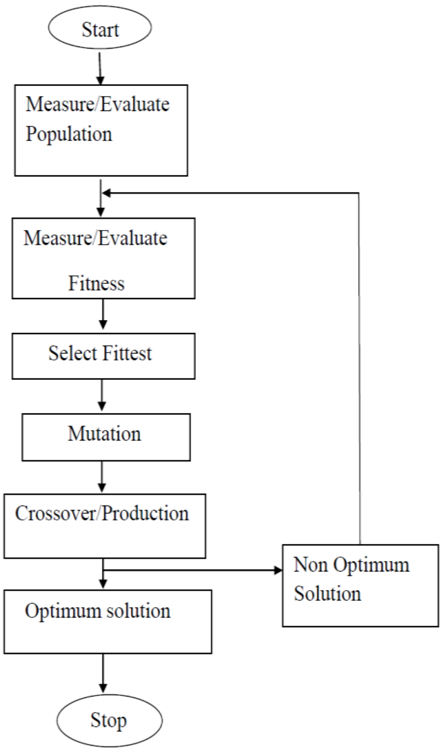

Fig.6 Genetic Algorithm process Flow chart

V. SIMULATION RESULTS

GA based load frequency controller for a two area interconnected power system with SMES and RFB are designed and implemented.

	With SMES conventional	**With RFB conventional**	**With SMES GA**	**With RFB GA**
Δf1	23	19	17	14
Δf2	21	19	17	13
ΔPtie	23	13	12	11

Table.1 Overshoot with different control schemes

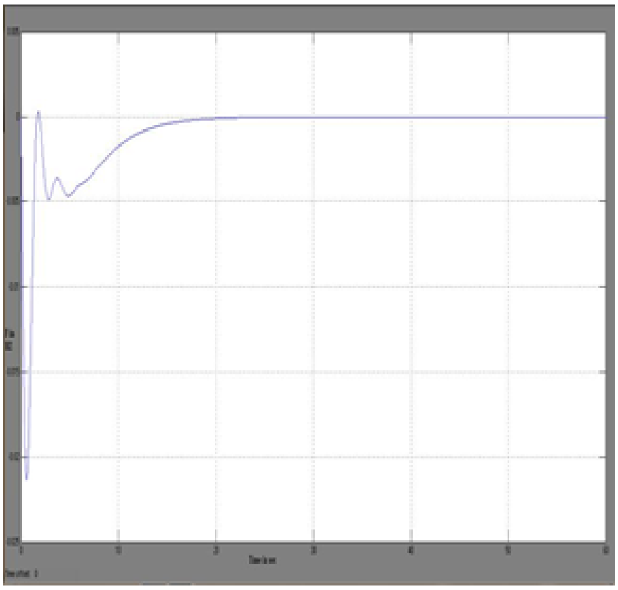

Fig.7 Δf1 for a two area interconnected power system with coordinated SMES

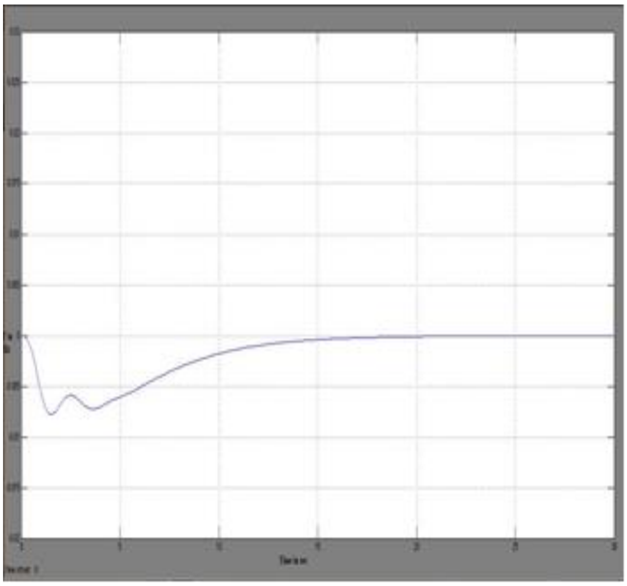

Fig.8 Δf2 for a two area interconnected power system with coordinated SMES

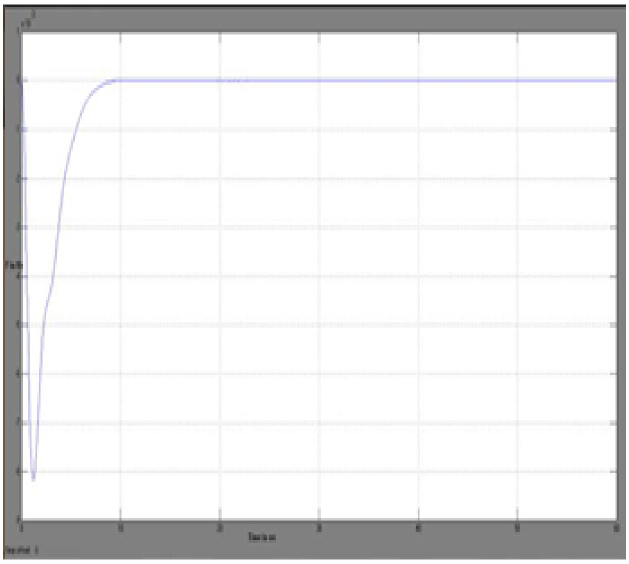

Fig.9 ΔPtie for a two area interconnected power system with coordinated SMES

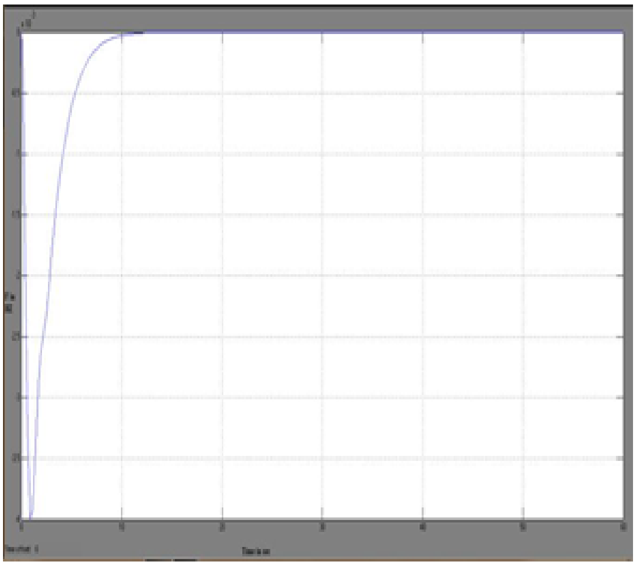

Fig.12 ΔPtie for a two area interconnected power system with coordinated RFB

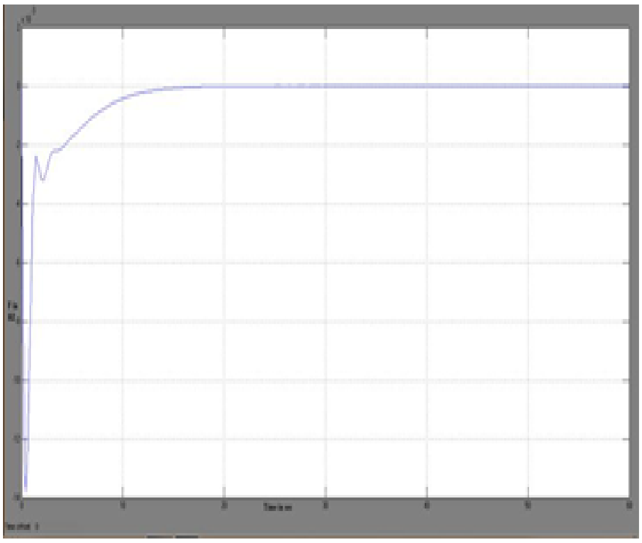

Fig.10 Δf1 for a two area interconnected power system with coordinated RFB

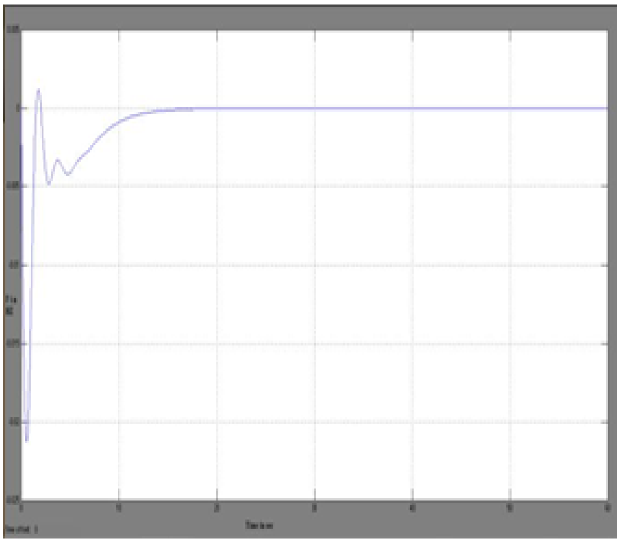

Fig.13 Δf1 for a two area interconnected power system with coordinated SMES using GA

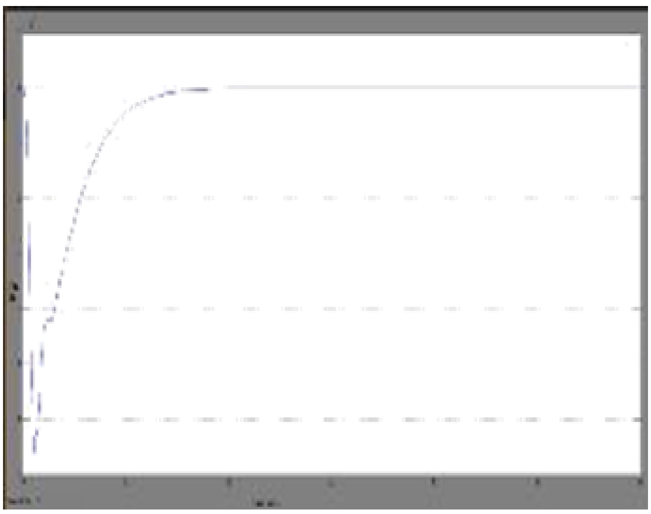

Fig.11 Δf2 for a two area interconnected power system with coordinated RFB

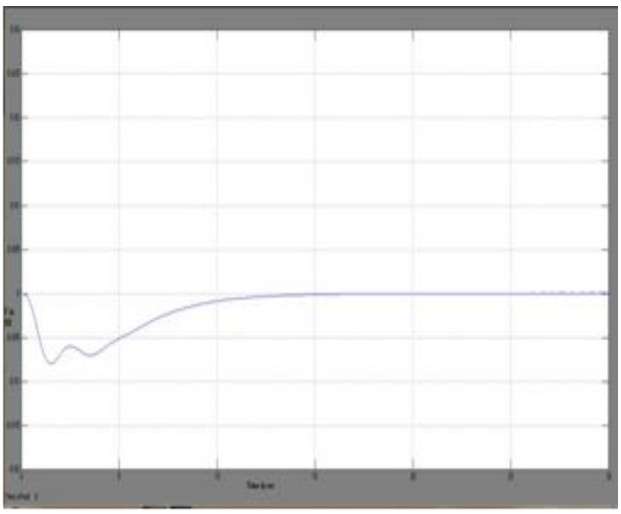

Fig.14 Δf2 for a two area interconnected power system with coordinated SMES using GA

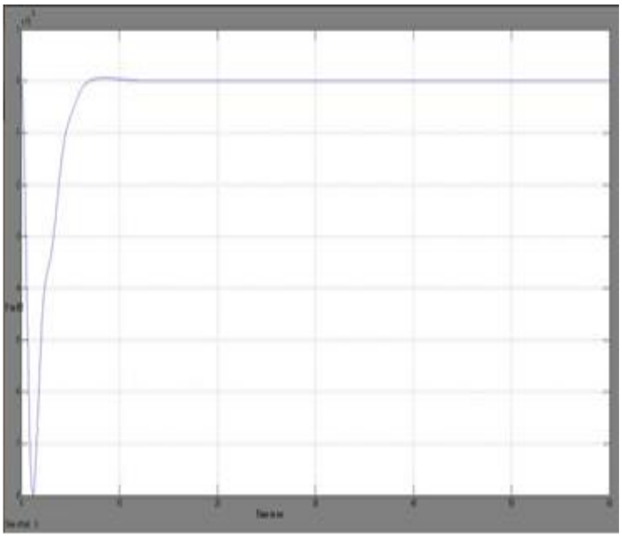

Fig.15 ΔPtie for a two area interconnected power system with coordinated SMES using GA

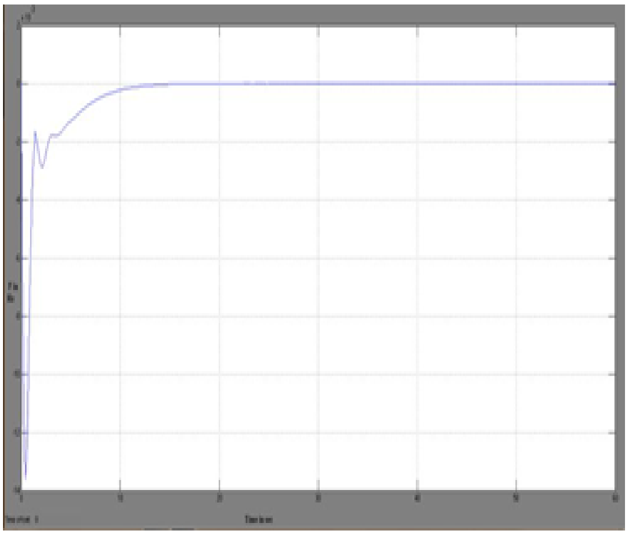

Fig.16 Δf1 for a two area interconnected power system with coordinated RFB using GA

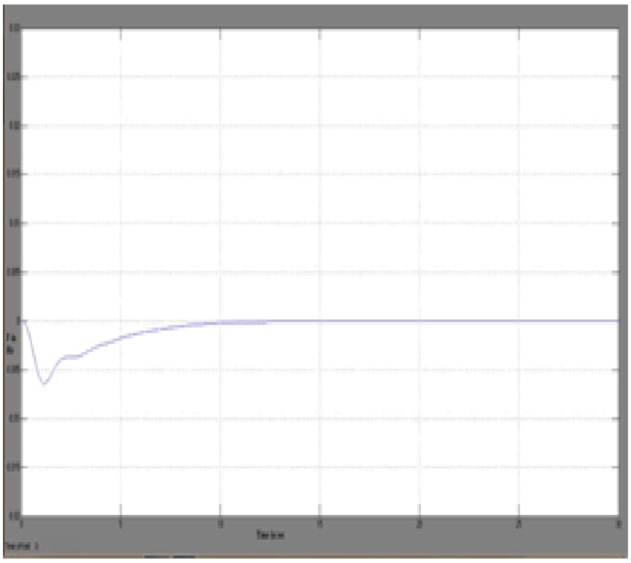

Fig.17 Δf2 for a two area interconnected power system with coordinated RFB using GA

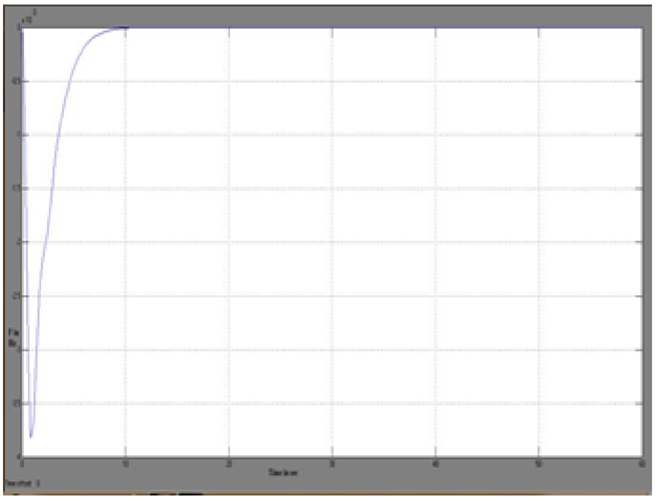

Fig.18 ΔPtie for a two area interconnected power system with coordinated RFB using GA

VI. CONCLUSION

In this proposed study, Genetic Algorithm based PI has been introduced for automatic load frequency control of a two area power system. For this purpose, first, more adaptive tuning mechanism for the PI controller parameters is obtained. It has been shown that the proposed control algorithms are effective and provides significant improvement in system performance.

It has been shown in the present thesis that small sized SMES units and RFB with suitable control can effectively reduce the frequency and tie-line power oscillations following sudden small load perturbations. This method of improving the load frequency control of power systems has the advantage that it does not require the governor or any other part of the power system to perform any sophisticated control action.

APPENDIX

Data for the interconnected two area power system,

Rating of each area=2000MW,

Base Power=2000MVA,

f=60 HZ ,a12=-1,

R1=R2=2.4 Hz/p.u,

Tg1=Tg2=0.08 µs,

Tt1=Tt2=0.3 µs,

Tps1=Tps2=20 µs,

β1=β2=0.425 p.u. MW/HZ

T12=0.545 p.u. MW/HZ

Pd1=0.01mp.u.MW

For SMES,

Ksm=0.12 KV/unit MW

Tsm=0.03 µs

For RFB,

Krfbi = 1.8, Tdi = 0, Tr = 0, Kr = 0

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BIOGRAPHY

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