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Automatic Generation Control of Power System for Diverse Energy Source with Optimization Techniques

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ABSTRACT: *The This paper emphasizes the significance of proportional-integral (PI) controller parameters using a genetic algorithm (GA) to reduce frequency control (FC) issues in a thermal, hydro and gas (THG) generating system for two area power system. The GA is used to solve the parameterization of the PI controller, resolving the perturbation issues of frequency. The system is tested for 1% step load perturbation (SLP) for its performance as PI controller parameters improves the dynamic response of the system as frequency in each area, and also deviations in tie line power after sudden load violation. This method is tested for MAT-Lab/ simulation 2013. The optimization shows the improved system for THG. The proposed model is integrated with battery energy storage system (BESS) and this model has been tested with step load perturbation (SLP) for 1%, 2%, and 3% i.e. verified with Mat-lab/ simulations. Justification has done for area control error (ACE) with frequency deviation & tie-line power for area-1 and area-2. The comparison done of PI controller with GA for proposed model & for BESS also the simulation results also successfully verified for GA.*

KEYWORDS – *Automatic generation control, genetic algorithm, tie-line, frequency control, area control error.*

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I. INTRODUCTION

For modern power systems, frequency must be constant. The frequency variation is not acceptable in current power system for world wide. The quality power supply can be achieved through the help of AGC for multi-area interconnected power systems with diverse energy sources. As robust power demand is a need of mankind globally, when load penetrates from its defined value with perturbation, the state of the system can change from normal to abnormal condition. AGC must identify the deviation in frequency and maintained it to constant system frequency.

As the operation of interconnected power systems should be balanced between generated powers with total load demand plus system losses. If operating point differ the system frequency can deviates, cumulative cause shows unbalanced power in the exchange of areas, result may undesirable effect [1-3]. AGC for two areas with proportional-integral-derivative (PID) investigated by Bhatti et al. [4] used generation source as thermal, gas & hydro. To optimize the gain Genetic algorithm (GA) was used for integral squared error (ISE) plus integral time absolute error (ITAE). Author worked for two area system under different normal loading conditions with 1% step load disturbance. The genetic algorithm and PID controller optimized for various cases. B. Mohanty et al. [5] worked for GRC and GDB in AGC with differential evolution algorithm based power system with non-linearity

A. K. Barisal et al. [4] worked with two unequal areas with diverse sources as thermal, hydro, and wind and diesel power plants. Comparison for optimization techniques bacteria foraging algorithm, particle swarm optimization (PSO) and improved PSO (IPSO) was used to optimize the PID controller the dynamic performance of two unequal areas with diverse sources was investigated and with the cost function integral of time multiplied absolute error (ITAE) considering 1% SLP.

AGC for two areas with proportional-integral-derivative (PID) investigated by Bhatti et al. [5] used generation source as thermal, gas & hydro. To optimize the gain Genetic algorithm (GA) was used for integral squared error (ISE) plus integral time absolute error (ITAE). In [6] worked for AGC with non-linearity and paper [7] for detailed review for AGC which contains the optimization techniques and their classification. N. R. Babu et al. [8] worked for AGC incorporated with HVDC and energy storage devices in a deregulated by using of performance index HPA-ISE. Y. Arya et al. [9] used the AGC for multi area thermal and thermal-hydro-gas power systems.

For this research article the following objectives have been investigated with input parameter and results justified by MATLAB simulation:

(a) Design and development of mathematical model of multi-area power system
with diverse energy sources.
(b) Investigating the effect of battery energy storage system in this model.
(c) To investigate proposed power systems model using PI controller conventional and genetic algorithm (GA) techniques.

II. POWER SYSTEM UNDER INVESTIGATION

Two area hybrid-Power System

This article proposes a multi source based two area power systems for AGC analysis under different approaches. The conventional generating stations like thermal and hydro stations are integrated with gas power plant to form area1 of the system. The area2 also comprises thermal, hydro and gas power plant to generate desired electrical power of the system. Each generating units are allocated with suitable participation factor for smooth distribution of applied load. The individual components of each generating unit are addressed through their transfer function expressions. The individual generating unit relies on separate controller to obtain secondary AGC loop of the system. The controllers are largely responsible for necessary control actions in the system.

The outputs are generator frequency Δf and ACE given by equation:

$ACE = B\Delta f + \Delta P_{Tie}$

where B is the frequency bias parameter.

The frequency-domain analysis, transfer function are used to model each component of the area. The simulation diagram of transfer function model for proposed two area power system is depicted in Fig.1 A brief discussion on individual generating station has been carried out and critically demonstrated in this section. The reheat based thermal plant is modeled with integrating various individual units i.e. governor, reheat turbine and non-reheat turbine. A. Abazari [10] in Figure 1integration of battery energy storage system (BESS) to AGC model.

III. DESIGN OF CONTROLLER AND OPTIMIZATION

A. Controller Design:

The control strategy of PI controller has smaller deviation in the first peak than the integral controller, but lesser value of settling time is obtained in case of only the integral controller. Also the response of the system is more oscillatory with PI controller compared with only the integral controller.

For $\left|\frac{d(ACE)}{dt}\right| > \varepsilon$; $\Delta PC = KP\ ACE(t)$; ACE is the area control error signal.

$\left|\frac{d(ACE)}{dt}\right| \leq \varepsilon$; $\Delta PC = KI \int ACE(t)$

The parameters of PI controller can be optimized using GA algorithm employing as an objective function as given in equation as bellow.

$$J = \int (|\Delta f_1| + |\Delta f_2| + |\Delta P_{Tie}|)$$

Where Δf_1 and Δf_2 are the system frequency deviations, a ΔP_{Tie} is the incremental change in tie line power.

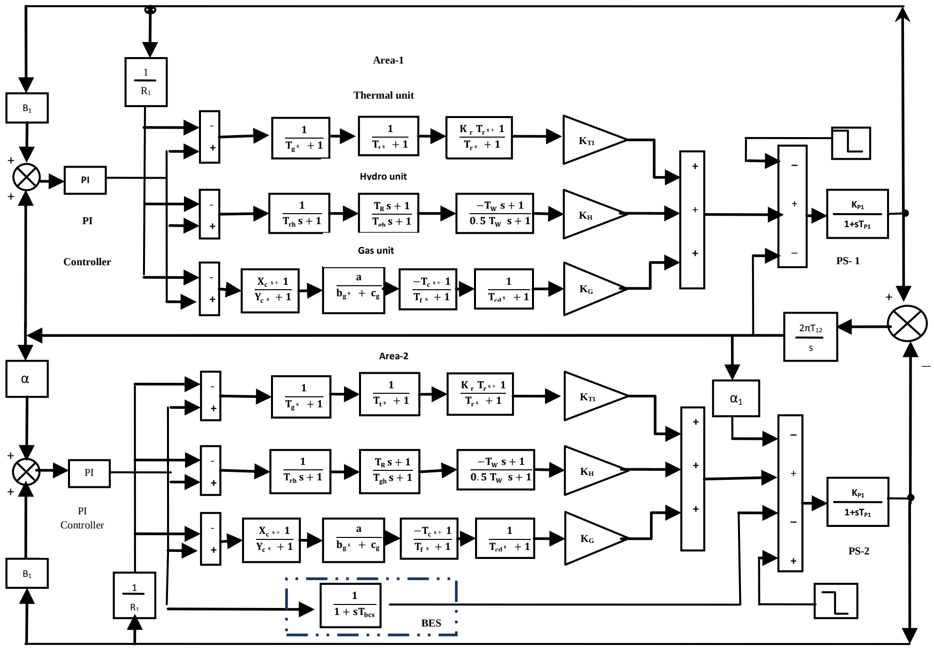


Fig1. Battery Energy Storage System with model of Two-Area (THG) System with PI Controller for Power System

B. Genetic Algorithm:

Genetic Algorithm (GA) is a search-based optimization technique based on the principles of Genetics and Natural Selection. It is frequently used to find optimal or near-optimal solutions to difficult problems which otherwise would take a lifetime to solve Fig 2.

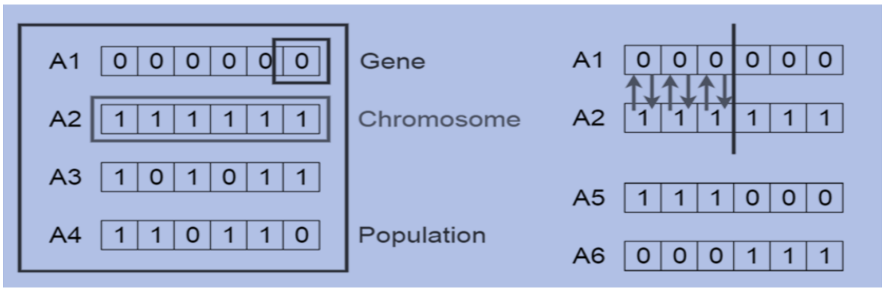


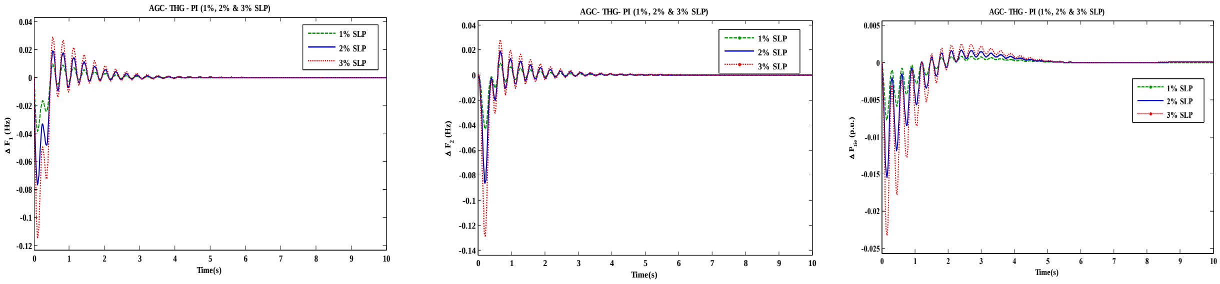
Fig2. Genetic algorithm

Process of genetic algorithm:

a) Randomly initialize population's p
b) Determine fitness of population
c) Until convergence repeat:
i) Select parents from population
ii) Crossover and generate new population
iii) Perform mutation on new population
iv) Calculate fitness for new population

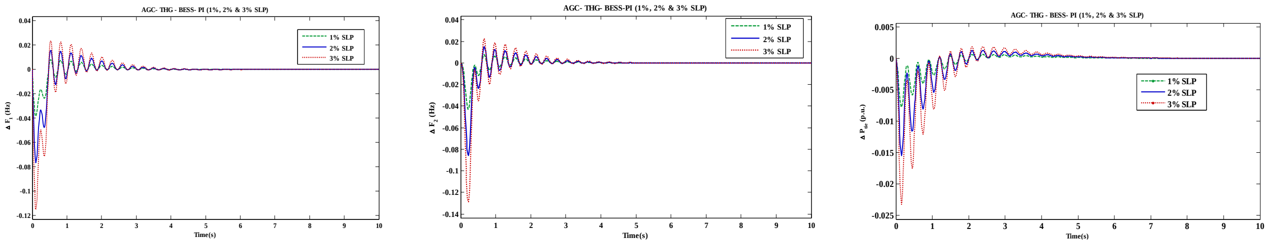
IV. DYNAMIC ANALYSIS OF SYSTEM

The dynamic analysis done for two area AGC model with PI controller for thermal, hydro and gas (THG) generating units. Step load perturbation (SLP) of 1%, 2% and 3% applied in area-1. The frequency deviation in area-1 is $\Delta \mathbf{F_1}$ and $\Delta \mathbf{F_2}$ for area-2 and Δ P-tie is tie line power, i.e. represented in simulation graph for Fig 3. Similarly Fig 4 represents simulation results of BESS with THG System. Fig 5 represent (a) , (b) and (c) for THG-PI, GA analysis (with / without) in proposed simulation model which shows 1% SLP. Similarly. Fig 6 represent (a), (b) and (c) for BESS with THG-PI GA analysis (with/without) in proposed simulation model which shows 1% SLP. Table 1 represents the AGC-THG-PI with BESS for GA optimized ITAE (J), frequency (Hz) and tie-line power (p.u. MW)



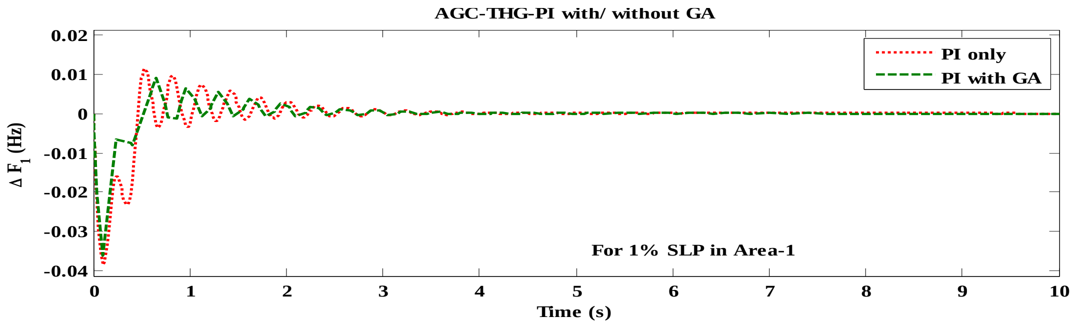
(a) Δ F_1(Hz) (b) Δ F_2(Hz) (c) Δ P tie (p.u.MW)

Fig 3. Simulation results of Two-Area Thermal, Hydro and Gas Plant (THG) System with PI Controller for Power System with (1%, 2% & 3% SLP).

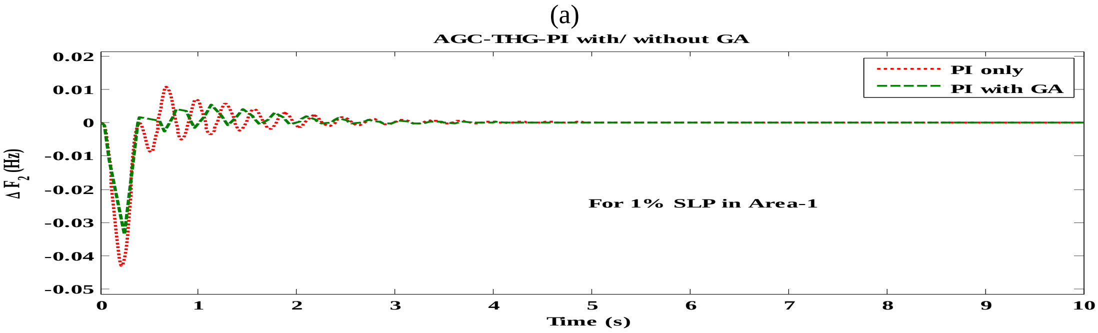


(a) Δ F_1(Hz) (b) Δ F_2(Hz) (c) Δ P tie (p.u.MW)

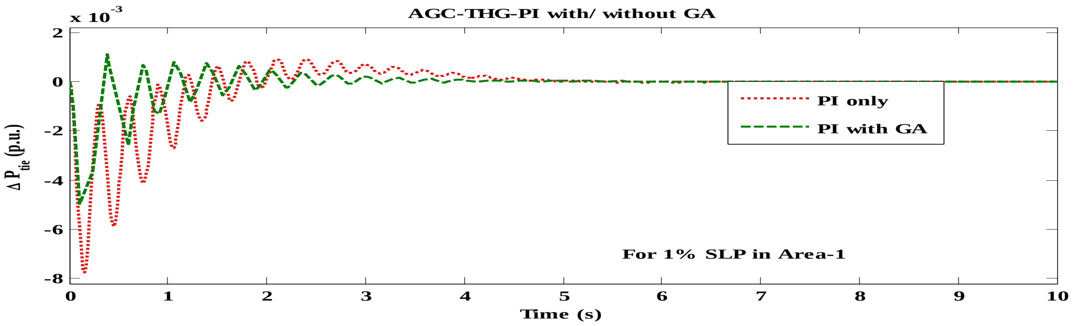
Fig 4. Simulation results of BESS with two-Area Thermal, Hydro and Gas Plant (THG) System with PI Controller for Power System with (1%, 2% & 3% SLP).



(a)

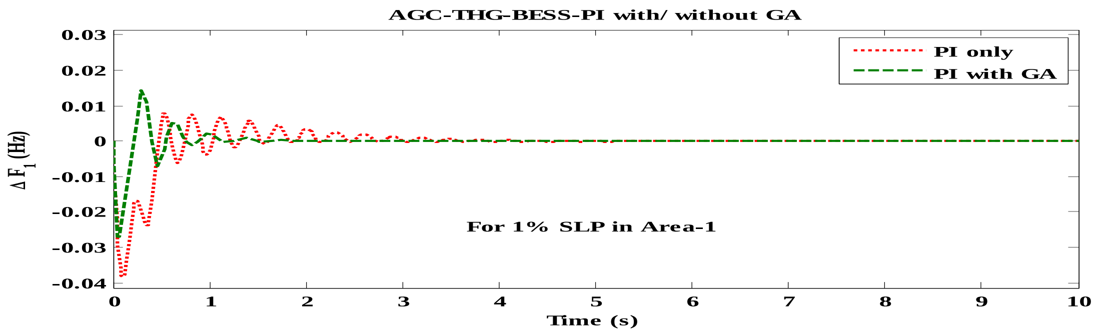


(b)

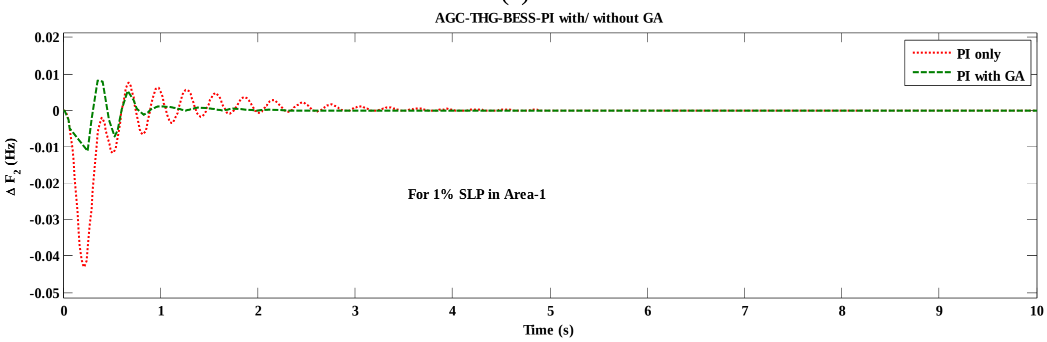


(c)

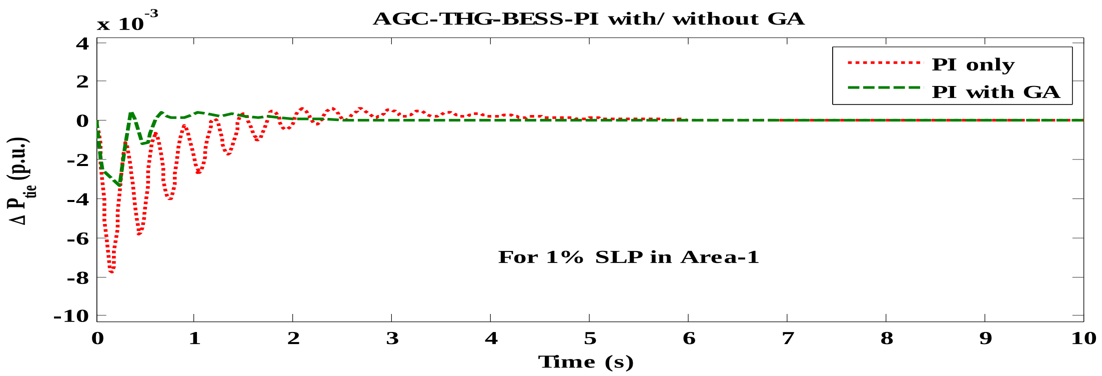
Fig 5(a, b, c) AGC- THG- PI with/ without GA for 1% SLP in Area -1



(a)



(b)



(c)

Fig 6(a, b, c) BESS with AGC- THG- PI with/ without GA for 1% SLP in Area -1

Table 1. AGC-THG-PI with BESS for GA represents ITAE(J), Frequency (Hz) and P-tie (p.u. MW)

Parameter for THG only (1% SLP)		Specification	PI only	PI with GA
J	ITAE	THG only	1.47	0.974
		with BESS	1.51	0.261
Settling Time S_T (sec)	ΔF_1	THG only	5.5	4
	ΔF_2		5.3	3.5
	ΔP_{Tie}		7.00	4.64
	ΔF_1	with BESS	4.802	2.1
	ΔF_2		5.082	2.1
	ΔP_{Tie}		6.602	2.997
Undershoot U_S(-ve)	ΔF_1	THG only	0.038	0.036
	ΔF_2		0.042	0.033
	ΔP_{Tie}		0.007727	0.004976
	ΔF_1	with BESS	0.03779	0.02832
	ΔF_2		0.04264	0.0111
	ΔP_{Tie}		0.007682	0.00333
Overshoot (O_S)	ΔF_1	THG only	0.011	0.009
	ΔF_2		0.0105	0.005
	ΔP_{Tie}		0.0009027	0.001113
	ΔF_1	with BESS	0.007794	0.01441
	ΔF_2		0.007542	0.008211
	ΔP_{Tie}		0.0006032	0.0004364

V. CONCLUSION AND SUMMARY

This research paper justified for proportional integral (PI) controller in frequency and tie-line power control for the system with different operating. As the design of controller with optimization techniques for optimal automatic generation control (AGC) for two area power system incorporated with diverse energy sources THG with optimization technique like GA has been utilized for best result. Penetration of BESS with proposed model have been investigated and verified for proposed model. The proposed model has been tested with SLP (1%, 2%, and 3%) and Mat-lab/ simulations verified their results. Dynamic responses have been done with the simulation also successfully verified for GA.

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Appendix:

Input data:

For PS [9]: Pri=2000MW; TPS=11.49s; KPS=68.9655 Hz/puMW; a12=-1; B=0.4312 puMW/Hz; R=2.4 Hz/puMW; TT=0.3s; TG=0.06; Tr=10.2s; Kr=0.3; TR=4.9s; TRH= 28.749s; TW=1.1s; TGH =0.2s; Y= 1.1s; X=0.6s; b=0.049s; a=1; c=1; TF =0.239s; TCR= 0.01s; TCD =0.2s; KT=0.5747; KH=0.2873; KG =0.2873; T12=0.0433; initial loading= 1740 MW; F°=60 Hz.

BESS[10]: Tcbs=0.2

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