Moacsa Based Controller Design for Automatic Generation Control of Deregulated Power Systems

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Abstract - In this paper, a novel design and performance analysis of Multi-Objective Artificial Cooperative Search Algorithm (MOACSA) based proportional integral controller for automatic generation control of multi-area deregulated power system is presented. The new multiobjective optimization algorithm has been developed based on the recently developed Artificial Cooperative Search algorithm. A two area, two unit thermal power systems having one reheat and one nonreheat turbine in each area is considered to exemplify the optimum parameter search. Unlike single objective methods, multiobjective optimization can find diverse solutions in a single run. The proposed Multiobjective Artificial Cooperative Search based controller is designed to satisfy the two objectives, namely, overshoot/ undershoot and settling time of the given power system. The proposed MOACSA is used for designing of PI controller for a two area interconnected deregulated power system parameters in deregulated environment. The presentation of projected approach is evaluated at all probable power scenarios that occur in a deregulated power environment. The simulation results reported in this paper demonstrates the effectiveness of the proposed MOACSA in the optimal tuning of the automatic generation control parameters in deregulated environment.

Keywords - Automatic Generation Control, Deregulated Power Systems, Multiobjective Artificial Cooperative Search Algorithm, Pareto Analysis.

1. INTRODUCTION

Automatic generation control (AGC) is an important mechanism in electric power systems, which balances generated power and demand in every control area to sustain the system frequency and power swap among areas at their prescribed values [1-5]. During the past decade, most of the AGC problems have been reported as a single objective optimization problem [6-10]. Real-world decision making problems need to accomplish a number of objectives, namely, maximize reliability, minimize deviations from desired levels, minimize cost, etc. Single-Objective optimization provides the “best” solution, which corresponds to the minimum or maximum value of an objective function. However, Multi objective optimization provides a set of compromised solutions with conflicting objectives. In the upcoming years, the research into multiobjective algorithms is likely to prove to be highly productive line of investigation. Hence, a Multiobjective Artificial Cooperative Search Algorithm (MOACSA) based intelligent controller for load frequency control of deregulated power systems has been presented in this paper.

Different control strategies have been projected to accomplish enhanced performance of interconnected power systems. Proportional plus integral controllers are conventionally preferred for AGC of interconnected power systems due to their natural simplicity, easy understanding, robust and decentralized nature of the control approach. The Integral Squared Error (ISE) principle is used for attaining the controller gain values [11]. Yet, the frequency deviations and tie-line power deviations continue for an extended period even though zero steady state errors are ensured. A rapid reduction in the large initial error has been observed by the controller designed on the basis of ISE criterion. For this reason, the system response is fast and oscillatory. Therefore, the system has poor relative stability. On the other hand, the controllers designed on the basis of MSM principle do not possess the natural good properties of the controller intended on the basis of ISE criterion apart from enhancement of stability [12]. Hence, it is predictable that an apt multi-objective control approach will be able to provide an enhanced solution for this problem.

In this research, the AGC problem is formulated as a Multi-Objective Optimization problem. A novel design procedure using Multi-Objective Artificial Cooperative Search Algorithm (MOACSA) is proposed for the first time to design an intelligent controller for load frequency control of interconnected deregulated power systems. The proposed controller fulfills two main objectives, namely Integral Squared Error (ISE) of the system and Integral of Time Absolute Error (ITAE). The projected control approach is based mainly on a compromise between Integral Squared Error criterion and Integral of Time Absolute Error criterion. The proposed controller is applied to a two-area two-unit interconnected deregulated thermal power system. Each area comprises of one reheat unit and one non-reheat unit.

2. DEREGULATED POWER SYSTEM MODEL

To improve the efficiency of operation of the existing power system scenario, major changes has been introduced into the power system structure. A Vertically Integrated Utility (VIU) structure exists in the traditional power system environment, where the generation, transmission and distribution are owned a single utility. In the deregulated power system structure, vertically integrated utilities do not exist. The generation companies GENCOs, transmission companies TRANSCOs, and distribution companies DISCOs act as different entities. Several GENCOs and DISCOs are present in the deregulated power system structure. A distribution company has the freedom of choice to have a contract with any generation company in another control area for transaction of power called “bilateral transactions.” All the bilateral transactions are done under the supervision of an independent system operator (ISO), for which AGC is another ancillary service [13].

In deregulated environment, the GENCOs and DISCOs can have various combinations of bilateral contracts among them. The bilateral contracts among various GENCOs and DISCOs can be realized effectively by using DISCO Participation Matrix (DPM) [14]. The DPM provides the details of the contracts between the GENCO and DISCO. The number or rows in DPM has to be equal to the number of GENCOs and the number of columns in DPM must be equal to the number of DISCOs in the deregulated environment. Each entry of DPM is a fraction of a total load power contract between a DISCO and GENCO in the system. The total sum of all the entries of DPM column is unity [15-19].

$$\sum_i \mathrm{cpf}_{ij} = 1$$

The block diagram of AGC model in deregulated scenario is given in Fig.1.The proposed deregulated power system is an interconnected two-area system with two GENCOs and two DISCOs in each area. The corresponding DPM matrix is as given below, where cpf represents the contract participation factor.

$$\mathrm{DPM}=\begin{bmatrix} \mathrm{cpf}_{11} & \mathrm{cpf}_{12} & \mathrm{cpf}_{13} & \mathrm{cpf}_{14} \\ \mathrm{cpf}_{21} & \mathrm{cpf}_{22} & \mathrm{cpf}_{23} & \mathrm{cpf}_{24} \\ \mathrm{cpf}_{31} & \mathrm{cpf}_{32} & \mathrm{cpf}_{33} & \mathrm{cpf}_{34} \\ \mathrm{cpf}_{41} & \mathrm{cpf}_{42} & \mathrm{cpf}_{43} & \mathrm{cpf}_{44} \end{bmatrix}$$

The off diagonal entries in the DPM represent the demand of DISCO in one area with the GENCO in another area.

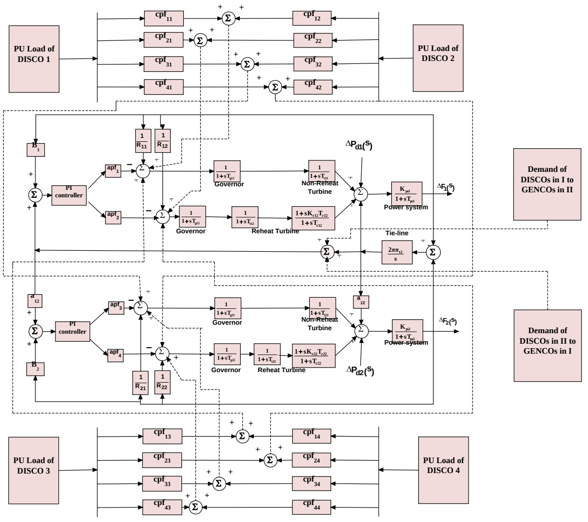

Fig.1.Two area AGC block diagram in deregulated environment

3. MULTI- OBJECTIVE EVOLUTIONARY ALGORITHM

Evolutionary Algorithms (EAs) are optimization techniques based on the principles of natural selection and population traits. They are iterative, population based approaches that use random selection and variation to generate new solutions. The EA is a global, robust, parallel search based optimization methodology that is capable to deal with ill-behaved problem domains, revealing features such as multimodality, discontinuity, time-variance, randomness and noise. It allows a notable level of flexibility with regard to performance evaluation and design requirement [20].

Evolutionary algorithms seem particularly desirable to solve multi-objective optimization problems, because they have good searching abilities in complex spaces and deal with a set of possible solutions which allows to find an entire set of solutions in a single run of the algorithms, instead of having to perform a series of separate runs as in the case of conventional mathematical programming techniques [21]. Real time problems frequently engage the simultaneous thought of multiple performance criteria. These objectives are repeatedly non-commensurable and are regularly in conflict with one another. Trade-offs exists between some objectives, where improving one objective will deteriorate in another. Instead of a single solution, a family of non-dominated solutions will exist. These Pareto Optimal solutions are those for which no other solutions from the set of optimal solutions can be said [20]. The Pareto optimal set of solutions for a two-objective case is shown in Figure 2.

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Fig.2. Pareto-optimal set of solutions for 2-objective problem

In Fig. 2, there are two objectives f1 and f2, to be simultaneously minimized. These objectives are competing with one another such that there is no single solution. Candidate solution point A has a lower value of f2, but a higher value of f1, than candidate point solution B. Thus, it is not possible to state that one point on the trade-off curve shown in Fig. 2 is better or worse than another. Such solutions are known as Pareto-optimal solutions to the multi-objective problem [22].

This selection method is based on the concept of dominance within the population. The best individuals are those which have fitness values on both criteria better than others. The individual is then marked as non-dominant. By this rule, many individuals in the population can be non-dominated, representing, locally optimal compromises between fitness criteria. These individuals are called “Pareto-optimal” solutions and constitute the most acceptable individuals for offspring production [21]. The central theme of Multi Objective Evolutionary Algorithm to date has been the search for a problem’s Pareto-front. This set can be quite large and hence, higher order information may be beneficially incorporated in order to direct the research to useful parts of the trade –off surface.

In the past, multiobjective problems have been treated as single objective problems by constructing a single function assigning relative weightage to each objective. This approach known as weighted- sum approach is unable to identify non-convex parts of the trade-off surface, potentially missing important areas for compromise, whereas, the EA selection operator can be used to identify degrees of Pareto optimality, thus enabling objectives to be considered individually. Hence, the need for a weighted combination of objectives and the need for a priori information are both avoided [20]. The robustness of the EA case of ill-behaved problems further increases the value of its utility.

In the upcoming years, the research into multiobjective evolutionary algorithms is likely to prove to be highly productive line of investigation. In this paper, MOACSA has been applied to the LFC problem with ISE criterion and ITAE criterion as competing objectives.

4. MULTI-OBJECTIVE ARTIFICIAL COOPERATIVE SEARCH ALGORITHM

In this section author need to mention his Artificial Cooperative Search (ACS) algorithm is a swarm intelligence algorithm, which has been developed for solving complex optimization problems. In ACS algorithm, a superorganism consisting of random solutions of the related problem corresponds to an artificial superorganism migrating to more productive feeding areas. ACS algorithm contains two superorganisms; α and β that have artificial sub-superorganisms equal to the dimension of the population (N). The dimension of the problem (D) is equal to the number of individuals within the related sub-superorganisms. In ACS algorithm, α and β superorganisms are used for the detection of artificial Predator and Prey sub-superorganisms. The Predator sub-superorganisms in ACS algorithm can pursue the Prey sub-superorganisms for a period of time while they migrate towards global optimum of the problem. A novel multiobjective approach has been developed from the Artificial Cooperative Search (ACS) algorithm.

Multi-objective optimization methods deal with obtaining optimal solutions to the problems with more than one objective. These multiple objectives frequently conflict with other objectives such that improving one of them will deteriorate other objective function. Hence, the optimal solution to a Multiobjective optimization problem is usually not a single value but as an alternative, a set of values known as the “Pareto-Optimal Set” [23-27]. No solution from this Pareto-Optimal set can be said to be better than the other solution. This method is realistic because the user acquires an occasion to examine various other tradeoff solutions sooner than settling on one particular optimal solution.

For this proposed power system model Integral Squared Error criteria and Integral of Time Absolute Error criteria are the objective functions.

Using ISE, $J_1 = \int \Delta F_i^2 + \Delta P_{tie1\ 2}^2 \; dt$ (1)

Using ITAE, $J_2 = \int_0^t \left|\Delta F_i^2\right| + \left|\Delta P_{tie1\ 2}^2\right| \; t.dt$ (2)

Mathematically, a multiobjective optimization problem can be described as:

Minimize/ Maximize fm(X), m = 1, 2…M; Subjected to J inequality constraints gj (X) ≥ 0, j = 1,2…J; and K equality constraints hk(X) = 0, k= 1,2…K; Xi(L) ≤ Xi ≤ Xi(U) , i=1,2……n (3)

The very last set of constraints are known as variable bounds, limiting every decision variable xi to acquire a value contained by a lower xi(L) and an upper xi(U) bound. There are M objective functions f(X) = (f_1(X), f_2(X)… f_M(X))T considered in the above formulation. A solution X is a vector of n decision variables. X = (x_1, x_2 …x_n) T.

An effort has been made in this segment, to apply MOACSA to the LFC problem with ISE criterion and ITAE criterion as conflicting objectives.

5. DESIGN OF OPTIMAL AGC CONTROLLER USING MOACSA

The LFC problem can be formulated as Minimize

$$f1(\mathbf{X}) = f1(x1, x2) = f1(kPm, kIm) = J1$$

$$f2(\mathbf{X}) = f2(x1, x2) = f2(kPm, kIm) = \eta$$

Subject to

$$k_{Pm}(L) \le k_{Pm} \le k_{Pm}(U)$$

$$k_{Im}(L) \le k_{Im} \le k_{Im}(U)$$

The proportional plus integral feedback gains obtained by ISE criterion (K_p, K_i) and those obtained by ITAE criterion (K_p’ , K_i’) are considered as the upper and lower limits for the two decision variables, namely K_{Pm} and K_{Im} while using MOACSA to the AGC problem. This design ensures that, the controller feedback gains will always be within the ranges of the gains obtained from the ISE criterion and the ITAE criterion. Therefore, the controller will guarantee the stability. Further the controller possesses improved stability when compared to the controller obtained using ISE criterion. Application of this controller for the interconnected deregulated power system is discussed in the next section.

6. SIMULATION/EXPERIMENTAL RESULTS

The LFC controller is designed using MOACSA with multiple objectives, namely the ISE criterion and ITAE criterion, and implemented in the deregulated interconnected two-area thermal power system with two units in each area. The system is simulated with the proposed controller for different deregulation scenarios and the corresponding frequency deviations and tie- line power deviations are plotted with respect to time. For easy comparison, the responses of frequency deviations and tie-line power deviations of the deregulated power system are shown along with the responses obtained with the optimal proportional plus integral controller designed on the basis of ISE criterion and ITAE criterion. The data required for the simulation of the proposed deregulated power system are given in [28].

Fig.3 shows the Pareto-optimal set values obtained using MOACSA algorithm. The solution is not a single value but instead a set of values and no solution from this set of optimal solutions can be said to be better than another solution. From the optimal set of values a most opt value for the controller has been selected and the simulations have been done as shown below. The red colored point in the Pareto optimal set curve is the most optimal which has been selected for simulation purpose and the corresponding value is given in table-1.

Table-1: Optimal gain values

Criteria	Kp	Ki	Objective value
ISE	0.6	0.19	151.7
ITAE	0.02	1.08	187.4
MOACSA	0.59	0.47	157.2

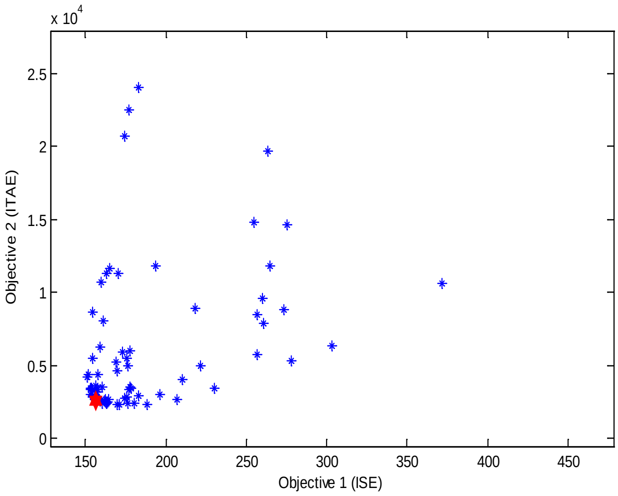

Fig. 3: Pareto optimal set

5.1 Scenario-1:

In this scenario of case study, the participation of all GENCOs is equally distributed in LFC operation. The area participation factors are $apf_1=apf_2=apf_3=apf_4=0.5$. The load changes are assumed to occur only in area 1, so the load is demanded by DISCO 1 and DISCO 2. The PU load of DISCO 1 and DISCO 2 are assumed as 0.1pu MW. Therefore the entries in DPM becomes as given below

$$DPM=\begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

The generation of GENCO (ΔPMi) is expressed in terms of contract participation factor (cpf) and load demand of DISCOs (ΔPLj) as given below

$$\Delta P_{Mi} = \sum_{j} cpf_{ij}\, \Delta P_{Lj} \qquad (6)$$

$$\Delta P_{Mi} = cpf_{i1}\Delta P_{L1} + cpf_{i2}\Delta P_{L2} + cpf_{i3}\Delta P_{L3} + cpf_{i4}\Delta P_{L4}$$

For this test case

ΔP_{M1} = (0.5x 0.1) + (0.5x 0.1) + 0 + 0 = 0.1p.u MW

ΔP_{M2} = (0.5x 0.1) + (0.5x 0.1) + 0 + 0 = 0.1p.u MW

ΔP_{M3} = 0 + 0 + 0 + 0 = 0 p.u MW

ΔP_{M4} = 0 + 0 + 0 + 0 = 0 p.u MW

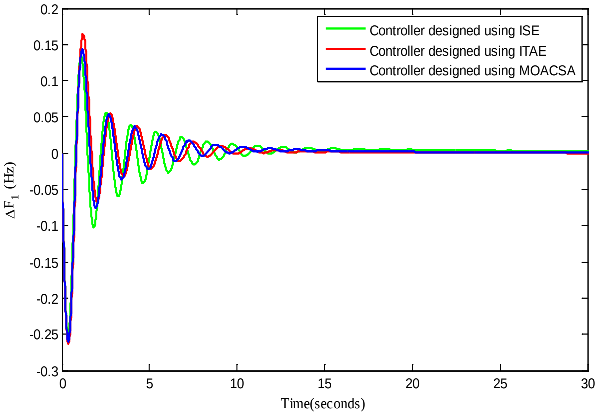

Fig. 4. Frequency deviation in area-I in Hz

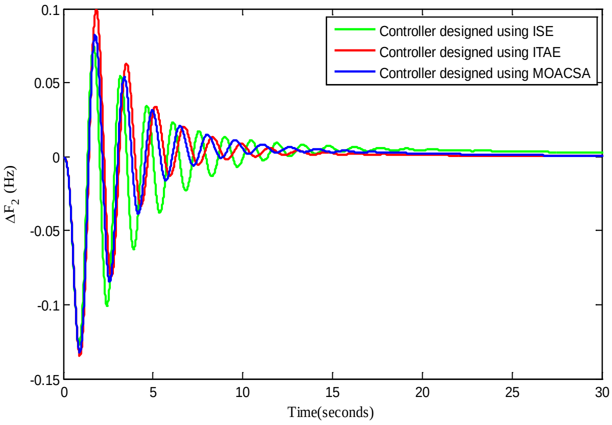

Fig.5. Frequency deviation in area-II in Hz

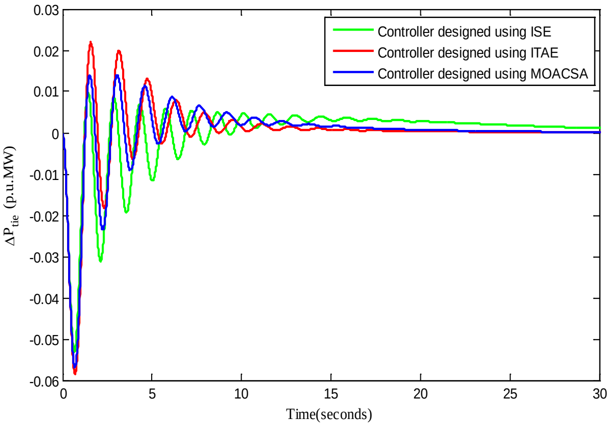

Fig.6. Tie-line power deviation p.u MW

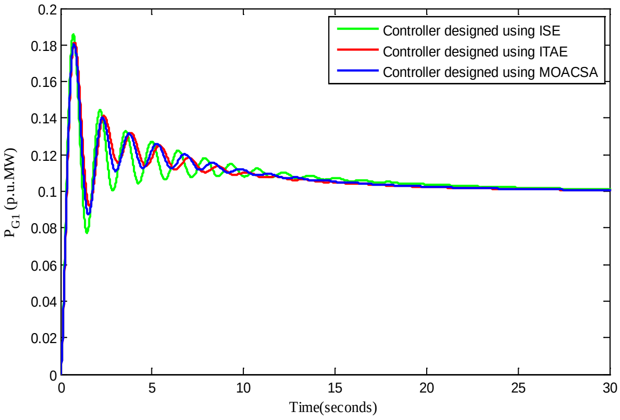

Fig. 7: Generation power of GENCO-1 in p.u MW

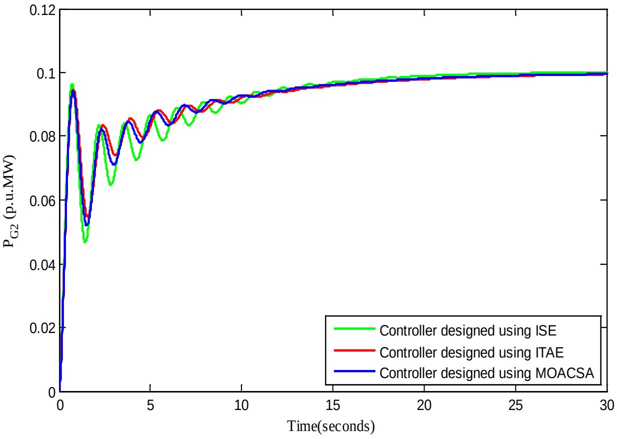

Fig. 8: Generation power of GENCO-2 in p.u MW

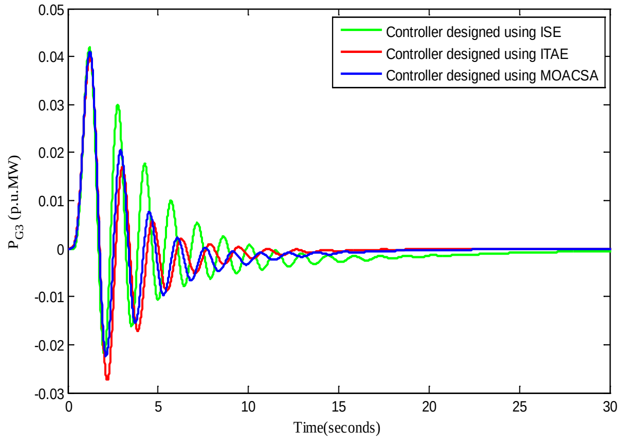

Fig. 9: Generation power of GENCO-3 in p.u MW

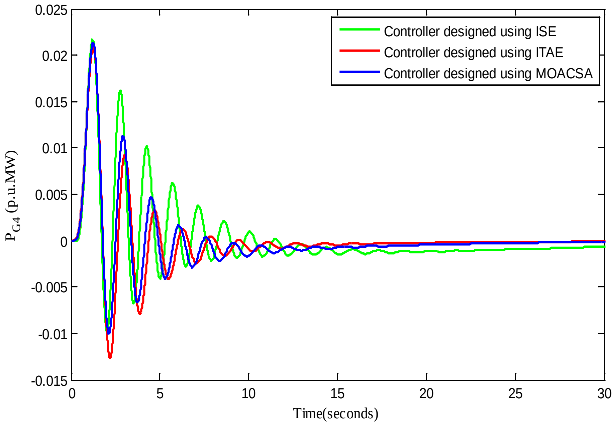

Fig. 10: Generation power of GENCO-4 in p.u MW

From the simulation results of scenario-1 it has been observed that the MOACSA tuned controller provides optimum results varying between ISE criteria and ITAE criteria. The scheduled tie-line power flows and generation power of the GENCOs are at their prescribed levels.

5.2 Scenario-2:

In this scenario of case study, the DISCOs have a contract with any GENCO in any other area as per the DPM. The area participation factors are apf1 = 0.75, apf2 = 0.25, apf3 = 0.5, apf4 = 0.5. Each DISCO demands 0.1 p.u MW power from GENCOs. Therefore the entries in DPM becomes as given below

$$\text{DPM}=\begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix}$$

The scheduled tie line power from area 1 to area 2 is calculated from the off diagonal blocks of the DPM using the following expression

$$\Delta P_{\text{tiescheduled}} = \sum_{i=1}^{2}\sum_{j=3}^{4} \text{cpf}_{ij}\Delta P_{Lj} \quad \sum_{i=3}^{4}\sum_{j=1}^{2} \text{cpf}_{ij}\Delta P_{Lj} \tag{7}$$

$$= (\text{cpf}_{13}+\text{cpf}_{23})\Delta P_{L3} + (\text{cpf}_{14}+\text{cpf}_{24})\,\Delta P_{L4} - (\text{cpf}_{31}+\text{cpf}_{41})\,\Delta P_{L1} - (\text{cpf}_{32}+\text{cpf}_{42})\,\Delta P_{L2}$$

$$= (0+0)0.1 + (0.3+0)0.1 - (0+0.3)0.1 - (0.25+0.25)0.1$$

$$= -\,0.05 \text{ p.u MW}$$

The generation of GENCO (ΔP_{Mi}) is calculated as follows,

For this test case

ΔP_{M1} = (0.5x 0.1)+(0.25x 0.1)+0+(0.3x0.1) = 0.105 p.u MW

ΔP_{M2} = (0.2x 0.1)+(0.25x 0.1)+0+0 = 0.045 p.u MW

ΔP_{M3}= (0x0.1)+(0.25x0.1)+(1x0.1)+(0.7x0.1)=0.195p.u MW

ΔP_{M4} = (0.3x0.1) + (0.25x0.1) + 0 + 0 = 0.055 p.u MW

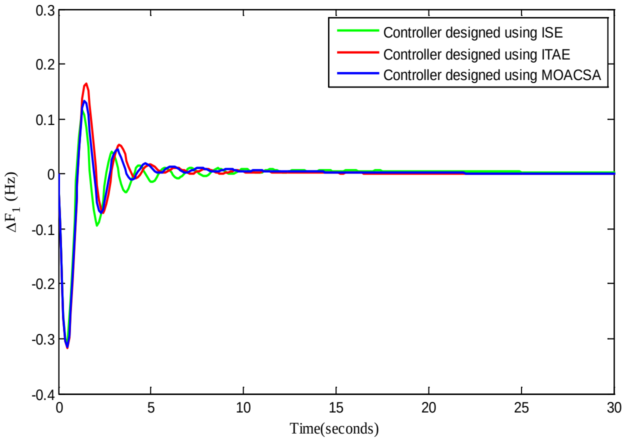

Fig. 11: Frequency deviation in area-1 in Hz

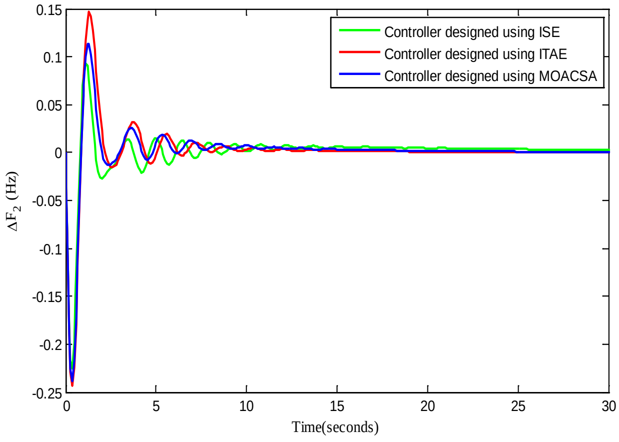

Fig. 12: Frequency deviation in area-2 in Hz

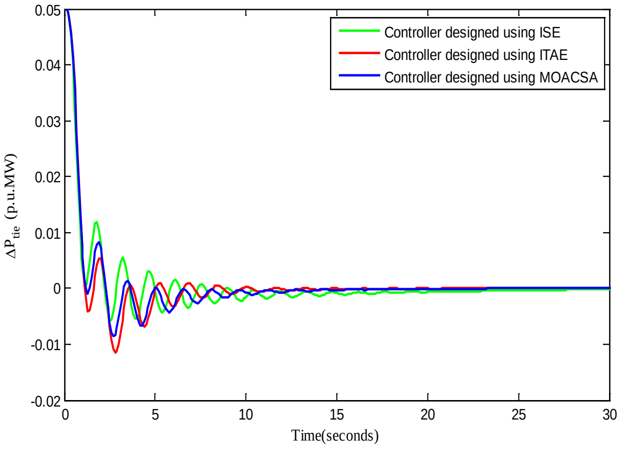

Fig. 13: Tie-line power deviation p.u MW

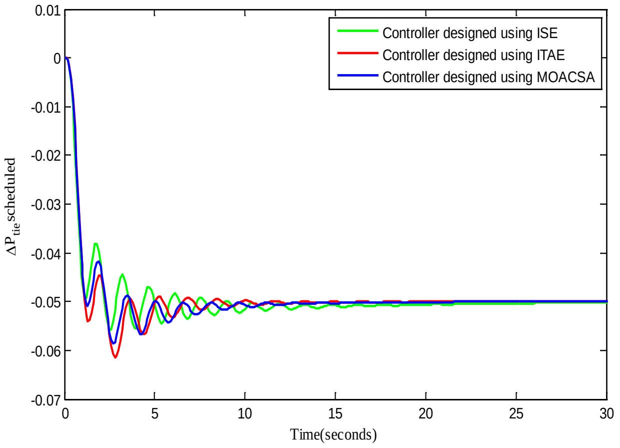

Fig.14: Scheduled tie-line power deviation p.u MW

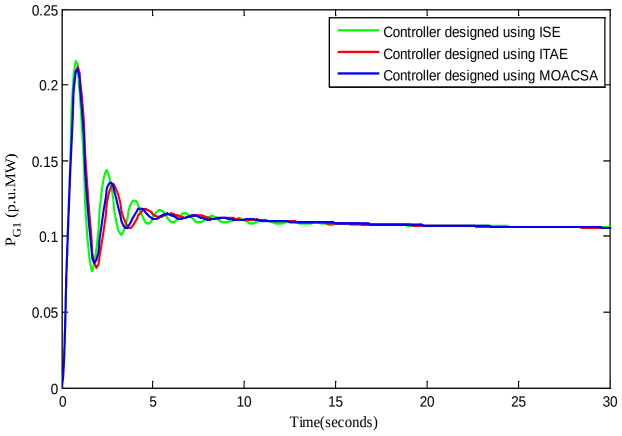

Fig. 15: Generation power of GENCO-1 in p.u MW

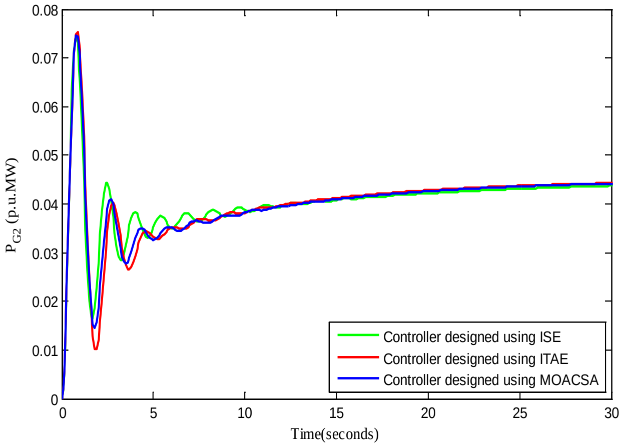

Fig.16: Generation power of GENCO-2 in p.u MW

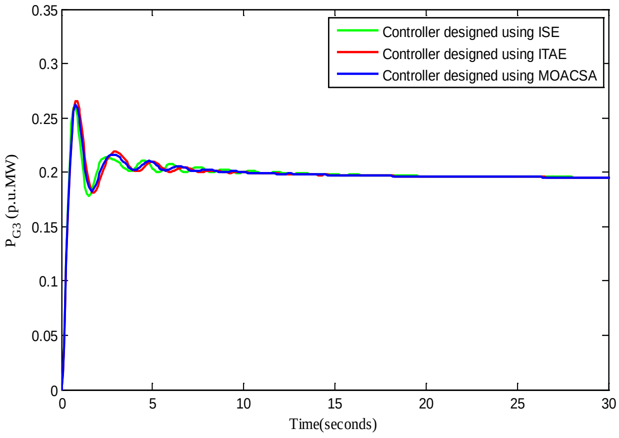

Fig. 17: Generation power of GENCO-3 in p.u MW

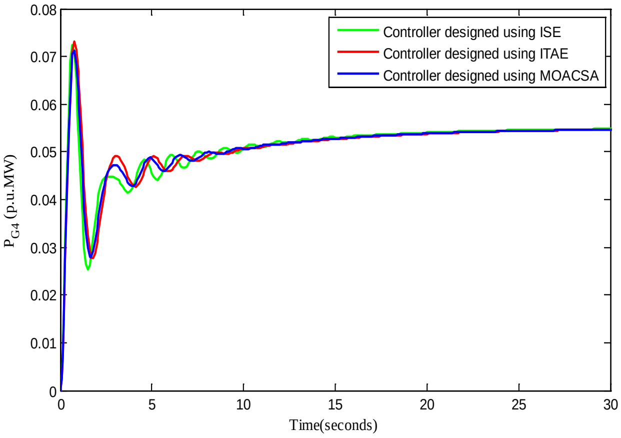

Fig. 18: Generation power of GENCO-4 in p.u MW

5.3 Scenario-3:

In this case, the violation of contract happens as DISCO 1 demands 0.1 pu MW more power than its contracted power. The uncontracted power will be supplied by the GENCOs present in the same area of the DISCO which violates the contract. The total load in area 1 is equal to the load of DISCO 1, load of DISCO 2 and the uncontracted load, which is equal to 0.3 pu MW. Similarly the load in area 2 is equal to the sum of the loads of DISCO 3 and DISCO 4 which is 0.2 pu MW. The DPM is same as in scenario 2. Figures show that Generation of GENCO 1 and GENCO 2 are affected by the uncontracted load of DISCO 1; whereas the generation of GENCO 3 and GENCO 4 remain unaltered due to the uncontracted load. The uncontracted load demand is met by the GENCOs in area 1. The frequency deviations and tie line power deviations are reduced effectively using the MOACS tuned controller.

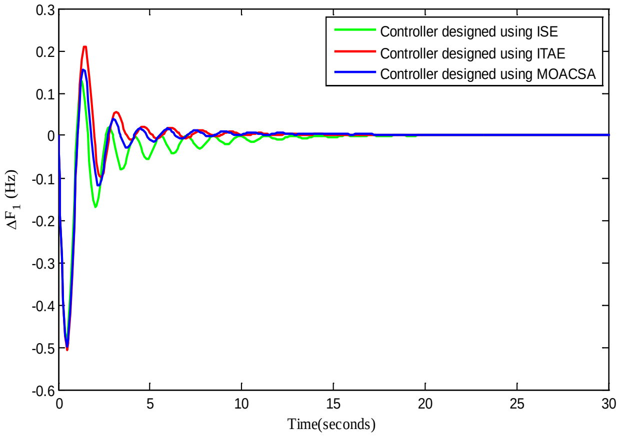

Fig. 19: Frequency deviations in area-I in Hz

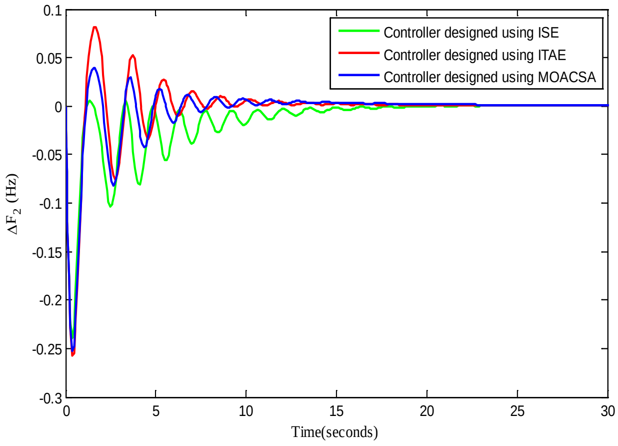

Fig. 20: Frequency deviations in area-II in Hz

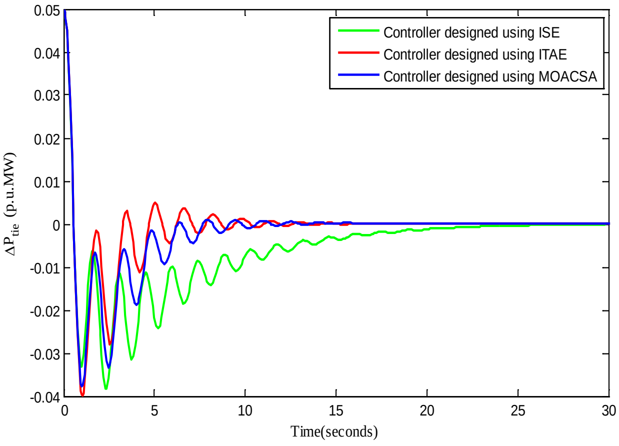

Fig.21: Tie-line power deviations p.u MW

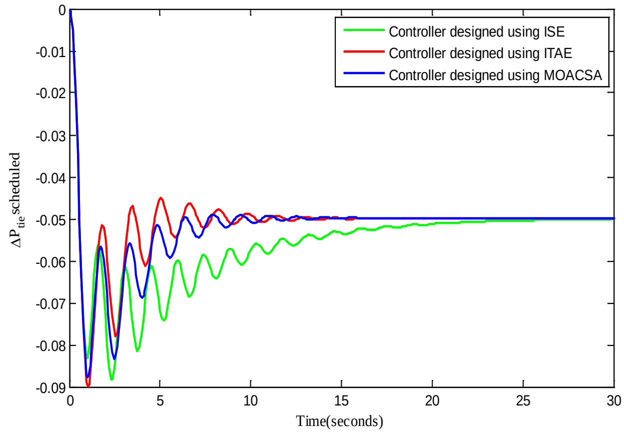

Fig. 22: Scheduled tie-line power deviations p.u MW

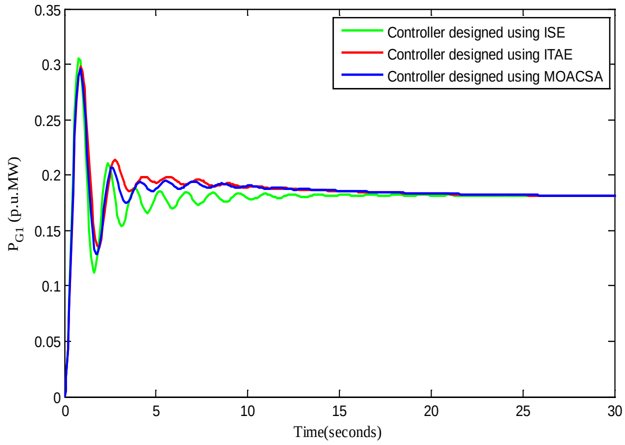

Fig.23: Generation power of GENCO-1 in p.u MW

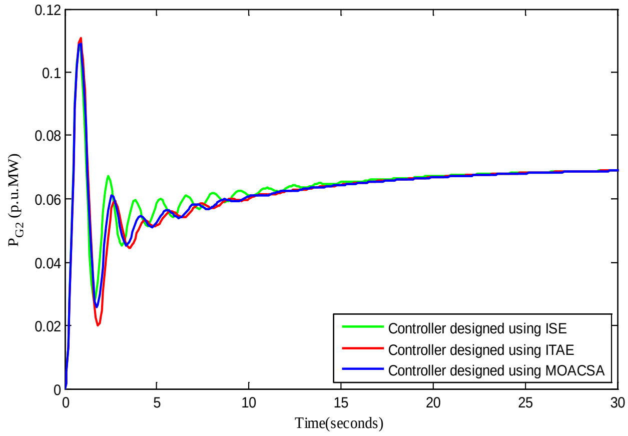

Fig.24: Generation power of GENCO-2 in p.u MW

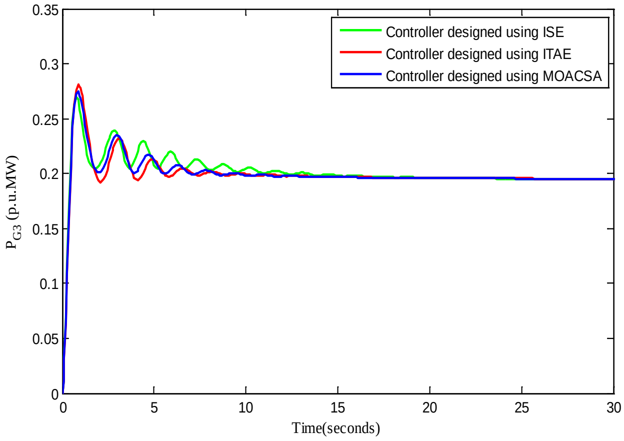

Fig. 25: Generation power of GENCO-3 in p.u MW

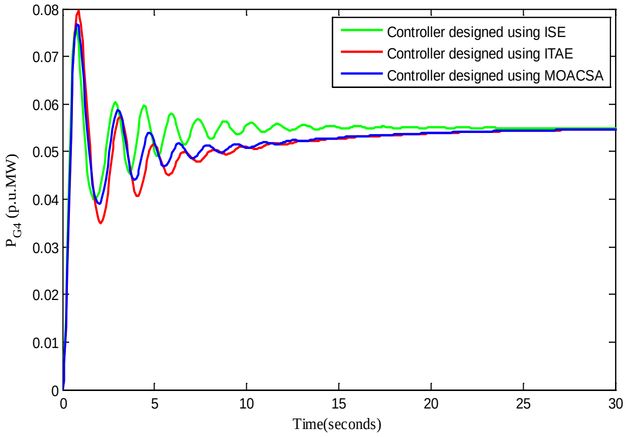

Fig. 26: Generation power of GENCO-4 in p.u MW

The area frequency deviations are measured in Hz, tie-line power deviations are measured in p.u MW and settling time in seconds. Table.2 presents the comparison of the system performances without non-linearities using MOACSA. The performance of controller designed using ISE, controller designed using ITAE and controller using MOACSA have been compared. The peak overshoot in area-1 with controller designed using ISE is 0.12 Hz, peak overshoot in area-1 with controller designed using ITAE is 0.17 Hz and peak overshoot in area-1 with controller designed using MOACSA is 0.14 Hz. The peak overshoot in area-2 with controller designed using ISE is 0.07 Hz, peak overshoot in area-2 with controller designed using ITAE is 0.1 Hz and peak overshoot in area-2 with controller designed using MOACSA is 0.082 Hz. The tie-line power deviation with controller designed using ISE is 0.009 Hz, tie-line power deviation with controller designed using ITAE is 0.022 Hz and tie-line power deviation with controller designed using MOACSA is 0.014 Hz. Similarly, the settling time of area-1frequency deviation using ISE is 21.22 seconds, the settling time of area-1 frequency deviation using ITAE is 19.42 seconds and the settling time of area-1frequency deviation using MOACSA

is 20.32 seconds. The settling time of area-2frequency deviation using ISE is 24.36 seconds, the settling time of area-2 frequency deviation using ITAE is 18.38 seconds and the settling time of area-2frequency deviation using MOACSA is 21.24 seconds. The settling time of tie-line power deviation with controller designed using ISE is 28.36 seconds, tie-line power deviation with controller designed using ITAE is 16.86 seconds and tie-line power deviation with controller designed using MOACSA is 22.34 seconds. From the detailed inspection, it is evident that MOACSA provides a compromising solution with the two conflicting objectives, namely, ISE and ITAE

Table 2. Comparison of the system performances

Controller description /Time domain specifications		Overall performance								
		Controller designed using ISE			Controller designed using ITAE			Controller designed using MOACSA		
		ΔF_1	ΔF_2	ΔP_{tie}	ΔF_1	ΔF_2	ΔP_{tie}	ΔF_1	ΔF_2	ΔP_{tie}
Scenario-1	os	0.12	0.07	0.009	0.17	0.1	0.022	0.14	0.082	0.014
	us	-0.23	-0.125	-0.05	-0.26	-0.14	-0.058	-0.24	-0.13	-0.056
	t_s	21.22	24.36	28.36	19.42	18.38	16.86	20.32	21.24	22.34
Scenario-2	os	0.11	0.08	0.05	0.16	0.15	0.05	0.125	0.12	0.05
	us	-0.28	-0.22	-0.005	-0.32	-0.24	-0.014	-0.3	-0.23	-0.008
	t_s	20.36	24.24	24.58	14.86	15.56	17.36	17.38	18.28	18.98
Scenario-3	os	0.12	0.01	0.05	0.21	0.08	0.05	0.14	0.04	0.05
	us	-0.47	-0.23	-0.033	-0.5	-0.25	-0.04	-0.48	-0.24	-0.038
	t_s	21.22	22.54	24.65	15.52	14.86	13.28	18.52	17.54	16.66

os – Over shoot (p.u MW); us – Under shoot (p.u MW); t_s- settling time seconds

The area frequency deviations are measured in Hz, tie-line power deviations are measured in p.u MW and settling time in seconds. Table.2 presents the comparison of the system performances without non-linearities using MOACSA. The performance of controller designed using ISE, controller designed using ITAE and controller using MOACSA have been compared. The peak overshoot in area-1 with controller designed using ISE is 0.12 Hz, peak overshoot in area-1 with controller designed using ITAE is 0.17 Hz and peak overshoot in area-1 with controller designed using MOACSA is 0.14 Hz. The peak overshoot in area-2 with controller designed using ISE is 0.07 Hz, peak overshoot in area-2 with controller designed using ITAE is 0.1 Hz and peak overshoot in area-2 with controller designed using MOACSA is 0.082 Hz. The tie-line power deviation with controller designed using ISE is 0.009 Hz, tie-line power deviation with controller designed using ITAE is 0.022 Hz and tie-line power deviation with controller designed using MOACSA is 0.014 Hz. Similarly, the settling time of area-1frequency deviation using ISE is 21.22 seconds, the settling time of area-1 frequency deviation using ITAE is 19.42 seconds and the settling time of area-1frequency deviation using MOACSA is 20.32 seconds. The settling time of area-2frequency deviation using ISE is 24.36 seconds, the settling time of area-2 frequency deviation using ITAE is 18.38 seconds and the settling time of area-2frequency deviation using MOACSA is 21.24 seconds. The settling time of tie-line power deviation with controller designed using ISE is 28.36 seconds, tie-line power deviation with controller designed using ITAE is 16.86 seconds and tie-line power deviation with controller designed using MOACSA is 22.34 seconds. From the detailed inspection, it is evident that MOACSA provides a compromising solution with the two conflicting objectives, namely, ISE and ITAE.

7. CONCLUSIONS

A novel Multi Objective Artificial Cooperative Search Algorithm based design of an intelligent controller for load frequency control of interconnected deregulated power systems has been presented in this chapter. The controller is designed using MOACSA with multiple objectives, which are the ISE criterion and ITAE criterion. This design has been effectively implemented in an interconnected two-area deregulated thermal power system with two generating units in each area. To investigate the effectiveness of the proposed approach, time domain simulations are carried out considering different contracted scenarios and the comparative results are presented. Simulation results reveal that the proposed controller provides good damping and reduced transient error and any additional enhancement in one of the design objectives will result in degradation of the other objective. It is to be noted that the proposed controller also satisfies all the requirements of Load Frequency Control. This procedure is practical because the consumer gets an occasion to explore a number of other trade-off solutions ahead of selecting one particular optimal solution.

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