Comparison of AGC Characteristics by using PI Controllers and Improved Bacteria Foraging Optimization Algorithm

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Abstract - **Simulteneous optimization of parameters like Ki, Ri and Bi has been done which grants not only the best dynamic response for the system but also permits us to use larger values of Ri than put into practice. The performance of IBFOA is investigated through the convergence characteristics and have been compared with the Pi controllers. The IBFOA is relatively faster in optimization such that there is drop in the computational load and also minimum use of computer resources. The IBFOA provides better stability as compared to PI controllers.**

keywords - **(IBFOA-Improved Bacteria Foraging Optimization Algorithm, AGC-Automatic Generation control, ALFC-Automatic Load Frequency Control)**

I. INTRODUCTION

Power systems are very large and complex electrical networks consisting of generation networks, transmission networks and distribution networks along with loads which are being disturbed throughout the network over a large geographical area. The rapid growth of industries has further lead to the increased complexity of the power system. The successful operation of interconnected power system requires the matching of total generation with total demand and associated system losses [1]. With time, the operating point of a power system changes, and hence, these systems may experience deviations in nominal system frequency and scheduled power exchanges to other areas, which may yield undesirable effects. In actual power system operations, the load is changing continuously and randomly. The ability of the generation side to track the changing load is limited due to physical/technical consideration, causing imbalance between the actual and scheduled generation quantities. This action leads to a frequency variation. The difference between the actual and the synchronous frequency causes mal operation of sophisticated equipment like power converters by producing harmonics [2].

In the power system, the system load keeps changing from time to time according to the needs of the consumers. Changes in real power affect mainly the system frequency, while reactive power is less sensitive to changes in frequency and is mainly dependant on changes in voltage magnitude. Thus active and reactive powers are controlled separately. The Load Frequency Control (LFC) loop controls the real power & frequency and Automatic Voltage Regulator (AVR) loop regulates reactive power & voltage magnitude. Load frequency control has gained in importance with the growth of interconnected systems and has made the operation of interconnected systems possible [3].

Since, frequency is greatly depends on active power and voltage greatly depends on reactive power, so the control difficulty in the power system may be divided into two parts. One is related to the control of active power along with frequency and the other is related to the control of reactive power along with voltage regulation. The active power control and the frequency control are generally known as the Automatic Load Frequency Control (ALFC) [3].

II. MAJOR OBJECTIVES OF AGC

In order to achieve integrated operation of a power system, an electrical energy system must be maintained at a desired operating level characterized by nominal frequency, voltage profile and load flow configuration. In an interconnected power system, it is desirable to maintain the tie-line flow at a given level irrespective of load change in any area. To accomplish this, it becomes necessary to manipulate the operation of main steam valves or hydro gates in accordance with a suitable control strategy, which in turn controls the real power output of the generators. The control of real power output of electric generators in this way is termed as Automatic Generation Control (AGC) [4][5].

(a) To take care of the required MW power output of a generator matching with the changing load.
(b) To take care of the appropriate value of exchange of power linking control areas.
(c) To facilitate control of frequency for larger interconnections.

III. AUTOMATIC GENERATION CONTROL

Today's power system consists of control areas with many generating units with outputs that must be set according to economics. The analysis and design of Automatic Generation Control (AGC) system of individual generator eventually controlling large interconnections among different control areas play a vital role in automation of power systems. The purposes of AGC are to maintain system frequency very close to a specified nominal value, to maintain generation of individual unit at the most economic value, to keep the correct value of tie-line power among different control areas. Automatic Generation Control is defined as the regulation of the power output of electric generators within a prescribed area in response to changes in system frequency, tie-line loading, or the regulation of these to each other, so as to maintain the scheduled system frequency and/or the established interchange with other areas within predetermined limits. AGC has evolved rapidly from the time when the function was performed manually, through the days of analog systems to the present day application of sophisticated direct digital control systems. Most of the work concentrates on the net interchange tie-line bias control strategy making use of the Area Control Error (ACE). The Automatic Generation Control (AGC) necessary to calculate area control error and monitor the system frequency and tie-line power flow computes the net change in generation required such that the time average of ACE is at a low value. The existence of ACE means that there is excess or deficient of spinning stored energy in an area and a correction to stored energy is required to restore the system frequency to scheduled values. The AGC problem has been extensively studied during the last four decades. Automatic Generation Control (AGC) is defined as the regulation of power output of controllable generators within a prescribed area in response to change in system frequency, tie-line loading or a relation of these to each other, so as to maintain the scheduled system frequency and/or to establish the interchange with other areas within predetermined limits. Thus a plan is required to maintain the frequency and the desired tie-line power flow as well to accomplish zero steady state error [1][6][7][8].

The two basic inter-area regulating responsibilities of AGC are as:

(a) When system frequency is on schedule, each area is expected automatically to adjust its generation to maintain its transfer with other areas on schedule, thereby absorbing its own load variations. As long, all areas do so; scheduled system frequencies as well as net interchange schedules for all areas are maintained.

(b) When system frequency is off schedule, because one or more areas are not fulfilling their regulating responsibilities, other areas are expected automatically to shift their respective net transfer schedules proportionally to the system frequency deviation and in direction to assist the deficient areas and hence restore the system frequency. The extent of each area’s shift of net interchange schedule is programmed by its frequency bias setting. Therefore, a control strategy is needed that not only maintains constancy of frequency and desired tie-power flow but also achieves zero steady state error and inadvertent interchange. Numbers of control strategies have been employed in the design of load frequency controllers in order to achieve better dynamic performance [9].

To keep interconnected power system reliable and safe, it is required to keep the tie-line power and system frequency within specified limits. In interconnected power system, when there is an uncertainty of load variation, the frequency and tie-line power deviate from their scheduled values, which lead to unsuccessful performance of entire grid system. There is an operational co-ordination which is required between generation and load demand to make system reliable & stable, that phenomenon is termed as automatic generation control (AGC) or Automatic load frequency control (ALFC) [10].

IV. CONCEPT OF CONTROL AREA

Almost all generating companies have tie-line interconnections to neighbouring utilities. Tie-lines allow the sharing of generation resources in emergencies and economy of power production under normal conditions of operation. For the purposes of control, the entire interconnected system is subdivided into control areas which usually confirm to the boundaries of one or more companies. The net interchange of power over the tie lines of an area is the algebraic difference between area generation and area load (plus losses). A schedule is pre-arranged with neighbouring areas for such tie-line flows, and as long as an area maintains the interchange power on schedule, it is evidently fulfilling its primary responsibility to absorb its own load changes. But since each area shares in the benefits of interconnected operation, it is expected also to share in the responsibility to maintain system frequency.

A control area is interpreted as a system where we can apply the common generation control or the load frequency control. Usually a self-governing area is made reference to as a control area. Electrical interconnection is very strong in every control area when compared to the ties in the midst of the adjoining areas. Within a control area all the generators move back and forth in logical and consistent manner which is depicted by a particular frequency. Automatic load frequency control difficulty of a bulky interrelated power system have been investigated by dividing the whole system into number of control areas and this power system is termed as multi-area power system. The interconnected large power system generally consists of different control areas and the system frequency and tie-line power remain constant for stable operation of the system. To make system stable, it is necessary to keep Area Control Error to zero value in each area. This is done by AGC action [11][12][13].

In the common steady state process, power systems every control area must try to counterbalance for the demand in power by the flow of tie-line power through the interconnected lines. Generally the control areas encompass only restricted right to use to the information of the total grid: they are able to manage their own respective buses however they cannot alter the parameters at the unknown buses directly. But an area is alert of the dominance of its nearby areas by determining the flow in and flow out of power by the side of its boundaries which is commonly known as the tie-line power. In every area, the power equilibrium equations are computed at the boundaries, taking into consideration the extra load ensuing from the power that is being exported. Later on, the areas work out the optimization problem in accordance to their objective function which is local [14].

Each control area should accomplish its individual load demand in addition to the power transfer all the way through tie-lines on the basis of communal agreement. Every control area must have adjustable frequency according to the control. Frequency changes occur because system load varies randomly throughout the day. This is the reason, why, an exact forecast of real power demand cannot be assured. The imbalance between real power generation and load demand (plus losses) throughout the daily load cycle causes kinetic energy of rotation to be either added to or taken from the on-line generating units, and frequency throughout the interconnected system varies as a result. Each control area has a central facility called the energy control centre, which monitors the system frequency and the actual power flows on its tie-lines to neighbouring areas. The deviation between desired and actual system frequency is then combined with the deviation from the scheduled net interchange to form a composite measure called the area control error, or simply ACE. To remove area control error, the energy control centre sends command signals to the generating units at the power plants within its area to control the generator outputs so as to restore the net interchange power to scheduled values and to assist in restoring the system frequency to its desired value. The monitoring, telemetering, processing, and control functions are coordinated within the individual area by the computer based automatic generation control (AGC) system at the energy control centres [8][15][16].

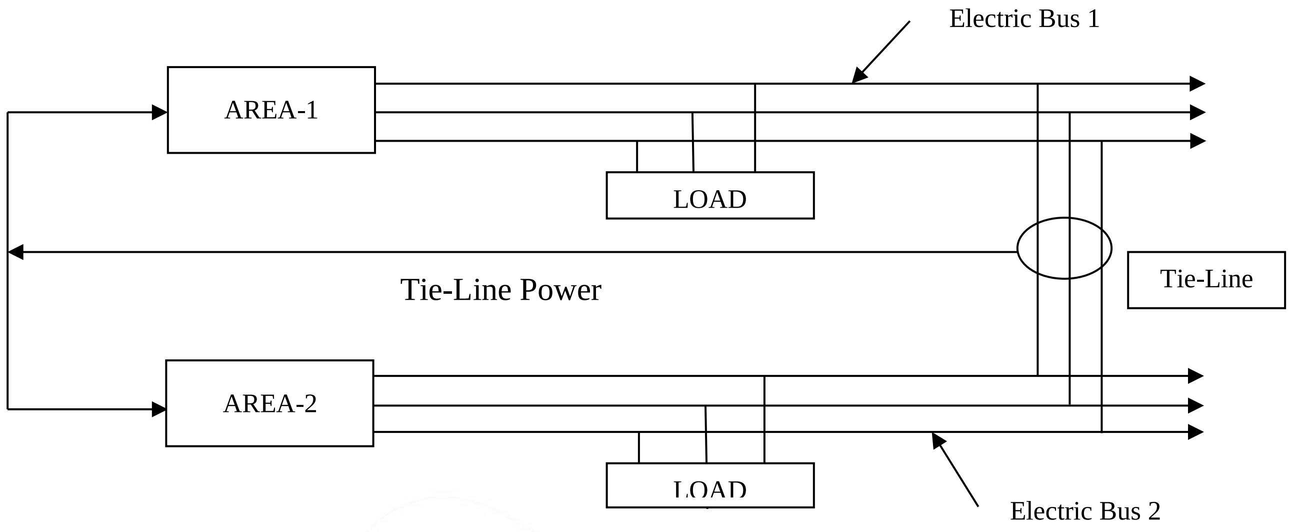

Fig1: Conventional Two Area System: Basic Block Diagram

The advantages of interc

- Reserve capacity is reduced and thus there is reduction in the installed capacity.
- For larger units, the capital cost per KW is reduced.
- Generators are used effectively.
- Generation is optimised, so there is reduction in the installed capacity.
- The reliability of the system is increased.
- Power can be supplied to larger area of population.

With these advantages, the interconnected system also faces some of the disadvantages. In an interconnected system, the faults get propagated, for which faster switchgear operation is required. High rating circuit breakers are to be used. For interconnected power system, qualified management staff and high skill manpower is required [17].

The Automatic Generation Control (AGC) necessary to calculate area control error and monitor the system frequency and tie-line power flow computes the net change in generation required such that the time average of ACE is at a low value. The existence of ACE means that there is excess or deficient of spinning stored energy in an area and a correction to stored energy is required to restore the system frequency to scheduled values. ACE which is defined as a linear combination of power net interchange and frequency deviations is generally taken as the controlled output of AGC. As the ACE driven to zero by the AGC, both frequency and tie-line power errors will be forced to zeroes. Each of the power generating area considers ACE signal to be used as the output of the plant. By making area control errors zero in all areas, all the frequencies along with errors in the tie-line power in the system can be made as zero.

In order to take care of the total exchange of power among its areas within the neighbourhood, ALFC utilises real power flow determinations of all tie-lines as emanating through the area and there after subtracts the predetermined interchange to compute an error value. The total power exchange, jointly with a gain B, known as the bias in frequency, as a multiplier with the divergence in frequency is known as the Area Control Error (ACE) specified by,

$$ACE = \sum_{K=1}^{k} P_k - P_s + B(f_{act} - f_0)MW \quad (1)$$

Where,

P_k = power in the tie-line (if out of the area the +ve)
P_s = planned power exchange
B = bias
f_{act} = actual frequency
f_0 = base frequency
Positive (+ve) ACE shows that the power flow is out of the area .

V. THREE AREA POWER SYSTEM COMPARED WITH PI AND IBFOA

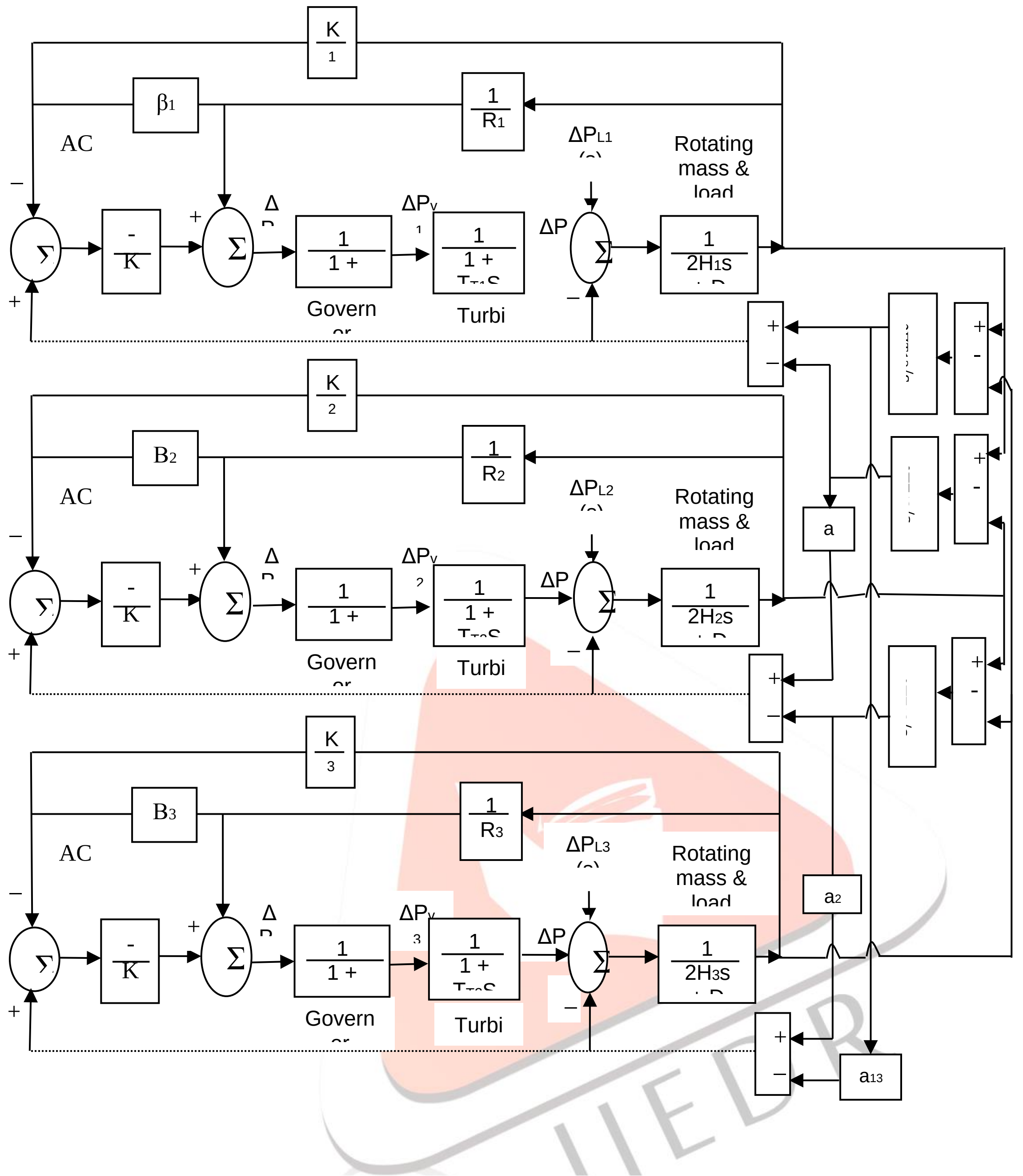

Fig 2: Three area power system by using secondary LFC loop

In a control area which is isolated, the incremental power ($\Delta P_G - \Delta P_D$) is the rate of rise of preserved kinetic energy due to rise in the load followed by a rise in the frequency. The power due to the tie-lines for each area is given below:

$\Delta P_1(s) = \Delta P_{12}(s) + a_{31}\Delta P_{31}(s)$ (2)
$\Delta P_2(s) = \Delta P_{23}(s) + a_{12}\Delta P_{12}(s)$ (3)
$\Delta P_3(s) = \Delta P_{31}(s) + a_{23}\Delta P_{23}(s)$ (4)

Control of tie-line bias is utilised to get rid of the steady state error because of frequency plus the power exchange due to tie-lines. This shows that all of the control areas should put in their share in frequency control, besides dealing with their own particular total interchange of power.

Let,
ACE_1 = area control error of area 1
ACE_2 = area control error of area 2
ACE_3 = area control error of area 3

ACE_1, ACE_2 and ACE_3 are shown as linear arrangement of frequency along with tie-line power error as follows:

$ACE_1 = \Delta P_{12} + b_1\Delta f_1$ (5)
$ACE_2 = \Delta P_{23} + b_2\Delta f_2$ (6)
$ACE_3 = \Delta P_{31} + b_3\Delta f_3$ (7)

Where, b_1, b_2 and b_3 are known as bias in frequency in area1, area 2 and area 3 respectively.

Area control error (ACE) is negative when the net power flow output from an area is very small or else when the frequency has dropped or both. During such situations, we need to increase the generation. When the area control error is positive, the generation is to be reduced [18][19][20].

VI. RESULTS AND CONCLUSION

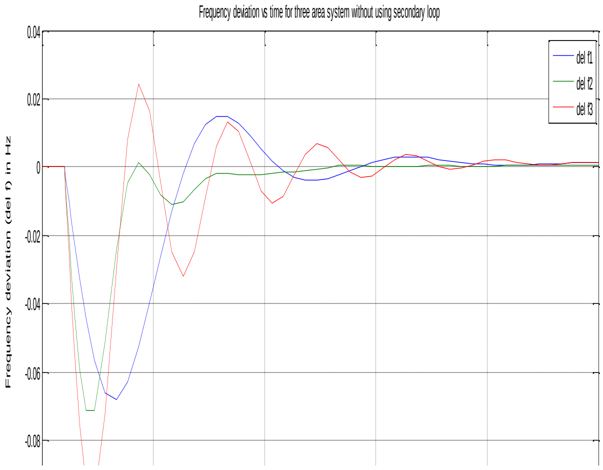

Fig 3: Frequency Deviation vs time using PI controllers

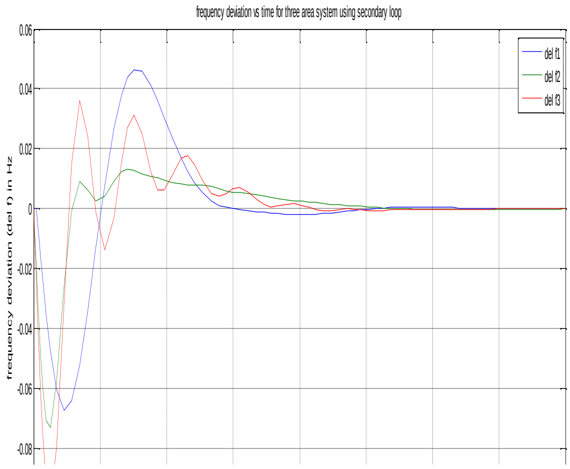

Fig 4: Frequency Deviation vs time using IBFOA

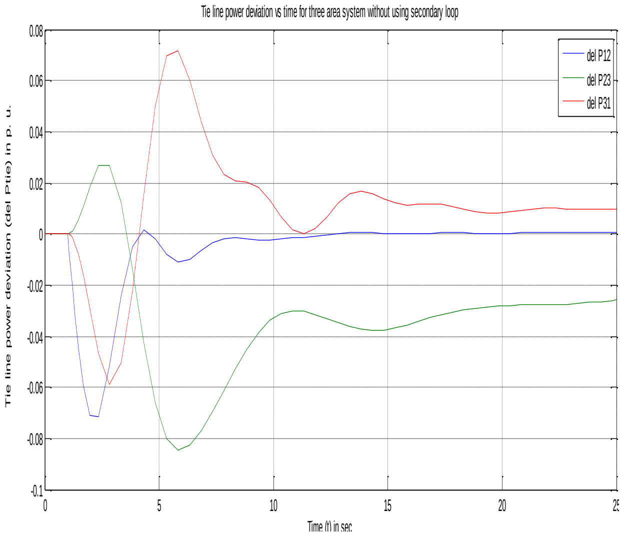

Fig 5: Tie-line power deviation vs time using PI controllers

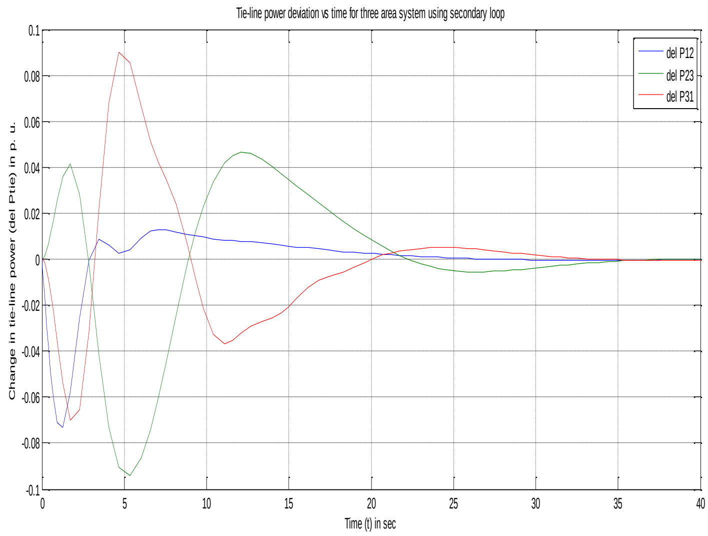

Fig 6: Tie-line power deviation vs time using IBFOA

increasing number of iterations and decreasing step size, the accuracy of the algorithm is significantly improved. The stability of the system tested is greatly improved with IBFOA as compared to the one with PI controllers. The introduction of an optimization technique i.e. Improved Bacteria Foraging Optimization Algorithmic program to change the values of the various parameters present in the power system under investigation so it can cope up with the changes in the load demand. As a result of which the changes in the frequency and also the tie line power is reduced and also the stability of the system is maintained. It is also seen that Bacteria Foraging technique has quicker convergence characteristics. Bacteria Foraging technique serves to be quite useful for obtaining the optimized values of the various parameters as compared to the general hit and trial technique which is extremely tedious and time taking method.

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