LOAD FREQUENCY CONTROL OF THREE AREA POWER SYSTEM USING BACTERIAL FORAGING OPTIMIZATION

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***Abstract*—*In the recent times there has been increase in the interconnected systems as far power systems are concerned due to increase in load demand. Load as well as power flow in the tie lines are varying dynamically. This robust control could be achieved with the help of BFO in the place of traditional system using proportional, PI and PID controllers. This is due to the fact that gain constants in the case of conventional controllers remain same throughout, for changes in the load value. But both active and reactive power demand is never study and change perpetually with rising and falling trend. So as to get rid of these disadvantages related to conventional controllers, number of schemes have been put forth in literature. The bacterial foraging optimization Algorithm technique is being developed, which is applied to load frequency control in a three area interconnected power system. The performance of the system is obtained by MATLAB Simulink tool.General hit and trial method in the simulation has some demerits which have insisted on using BFOA for obtaining the desired values of the different parameters. This will help the industries concerning power for simpler as well as cheaper realization of the governor. The Bacteria Foraging Algorithm is relatively faster in optimization such that there is drop in the computational load and also minimum use of computer resource utilization.*

Keywords— Automatic Generation Control (AGC), Load Frequency Control(LFC), Bacterial Foraging Optimization Algorithm (BFOA),Change In Frequency(Del F), Proportional Gain(Kp)

1. INTRODUCTION

The power system consists of several interconnected control areas, any sudden changes in the load causes frequency fluctuations. So, Automatic Generation Control (AGC) plays a very important role in an interconnected power system for supplying electric power with good quality. One of the main objectives of AGC is to control power system frequency at nominal value and power flows over tie line at desired level. It also improves the reliability of the power system and makes it more adequate. Any fluctuation in the load demand causes abnormal conditions, such as outages of generation, lead to mismatches in frequency and scheduled power interchanges between areas. So, there is a need for a supplementary control for these mismatches [1].

A decently outlined power framework ought to have the capacity to give the satisfactory levels of power quality by keeping the frequency and voltage size inside middle of as far as possible.

Changes in the power system load influences chiefly the system frequency, while the reactive power is less delicate to changes in frequency and is fundamentally reliant on vacillations of voltage size. So the control of the true and reactive power in the power system is managed independently. The load frequency control fundamentally manages the control of the system frequency and genuine power in as much as the programmed Voltage controller circle directs the progressions in the reactive power and voltage extent. Load frequency control is the premise of numerous progressed ideas of the vast scale control of the power system.

As the loading in a power system is not constant so the controllers for the system must be aimed to provide quality service in the power system. The power flow and frequency in an interconnected system is well regulated by AGC. The main purpose of the AGC is to retain the system frequency constant and almost inert to any disturbances. Generally two things are being controlled in AGC i.e. voltage and frequency. Both have separate control loops and independent of each other. Apart from controlling the frequency the secondary majors is to maintain a zero steady state error and to ensure optimal transient behavior within the interconnected Areas. The objective is to design a controller to apprehend preferred power flow and frequency in multi-Area power systems.

Power systems are very large and complex electrical networks consisting of generation networks, transmission networks and distribution networks along with loads which are being distributed throughout the network over a large geographical area [12]. In the power system, the system load keeps changing from time to time according to the needs of the consumers. So properly designed controllers are required for the regulation of the system variations in order to maintain the stability of the power system as well as guarantee its reliable operation.

The rapid growth of the industries has further lead to the increased complexity of the power system. Frequency is mainly dependent on active power and the voltage greatly depends on the reactive power. So the control difficulty in the power system may be divided into two parts.

One is related to the control of the active power along with the frequency whereas the other is related to the reactive power along with the regulation of voltage [9]. The active power control and the frequency control are generally known as the Automatic Load Frequency Control (ALFC).

Basically the Automatic Load Frequency Control (ALFC) deals with the regulation of the real power output of the generator and its frequency (speed). The primary loop is relatively fast where changes occur in one to several seconds. The primary control loop reacts to frequency changes through the speed governor and the steam (or hydro) flow is managed accordingly to counterpart the real power generation to relatively fast load variations.

Load disturbance due to the occurrence of continuous and frequent variation of loads having smaller values always creates problem for ALFC. Because of the change in the active power demand/load in an area, tie-line power flows from the interconnected areas and the frequency of the system changes and thus the system becomes unstable. So we need Automatic Load Frequency Control to keep up the stability at the time of the load deviations. This is done by minimizing transient deviations of frequency in addition to tie-line power exchange and also making the steady state error to zero [3]. Inequality involving generation with demand causes frequency deviations. If the frequency is not maintained within the scheduled values then it may lead on the way to tripping of the lines, system collapse as well as blackouts.

2. CONCEPT OF CONTROL AREA

A control is interpreted as a system where we can apply the common generation control or the load frequency control scheme. 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 Controls difficulty of a complex inter connected power system have been investigated by dividing the whole system into number of control areas and termed as multi-area [4].

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.

3. CHARACTERISTICS OF A PROPERLY DESIGNED POWER SYSTEM

- It should supply power everywhere the customer demands practically.
- It should always supply power.
- It should always supply the ever changing load demand.
- The supplied power should be of good quality.
- The supplied power should be economical.

4. ADVANTAGES OF ALFC IN MULTI AREA SYSTEM

- The ALFC helps to diminish the transient deviations in addition to making the steady state error to zero.
- It also holds system frequency at a specified value.
- The ALFC also collaborate in keeping the net power interchange between the pool members at the predetermined values.

5. WHY INTER-CONNECTION OF AREAS

Due to increase in demand created by rising population and rapid industrialization, there is necessity of interconnected power system; there was a demand for larger bulk of power with increased reliability so there was interconnection of neighboring plants.

6. LITERATURE REVIEW

The PI controller parameters derived from conventional or trial-and-error methods can't have sensible dynamical act for a large variety of operating circumstances and changes in load in multi-area power system. To solve this difficulty, decentralized LFC combination is developed as an H-∞ control problem plus worked out by means of iterative linear matrix inequalities algorithmic rule to style sturdy PI controllers in multi-area power systems as shown in [5].

In the paper [6] a unified PID tuning technique dependent on two-degree-of-freedom for LFC of power system is discussed. Also time domain act in addition to robustness of consequential PID controller is associated to two regulation constraints as well as its robustness is discussed.

Simulation results shows improvement in damping of power systems. The additional degree-of freedom cancels the impact of unwanted poles of the disturbance, improving the disturbance reduction performance of system having closed-loop.

A lot of work has been done related to automatic load frequency control in power systems.

Load variations give rise to drifts in frequency along with voltage consequential in reduction of generation because of line tripping as well as blackouts. These variations are reduced by AGC that constitutes of two sections namely LFC and AVR. In the paper [7] simulation analysis is dispensed to comprehend operation of LFC by rising models in SIMULINK that helps to know the principles and various challenges relating to LFC.

BFO Algorithm emerged as a possible solution for many search and optimization problems. BFO may be viewed as an evolutionary process where in the population of feasible solutions to the optimization problem evolves over a sequence of iterations. Today several papers have been written on the applications of BFO. It is a true metaheuristic, with dozens of application areas. It can be well applied for getting optimized value of Kp, Ki & Kd which provide good tuning of controllers. Simulation is carried out using MATLAB to get the output response of the system. In the proposed method, as graph shows Bacterial Foraging Controller gives better result as compare to conventional controller. Our goal in the end is to design a control system that serves the power network for better performance and better power services in terms of consumption and supplement [11]

7. THREE AREA SYSTEM

A three area interconnected system is shown in Fig.1. Due to change in load there is change in the steady state frequency (f).

The three area interconnected system consists of three interconnected control areas. There is flow of tie line power as per the changes in the load demand due to the interconnection made between the control areas.
Thus the overall stability of the system is maintained at a balanced condition in spite of the constant variations in the load and load changes.

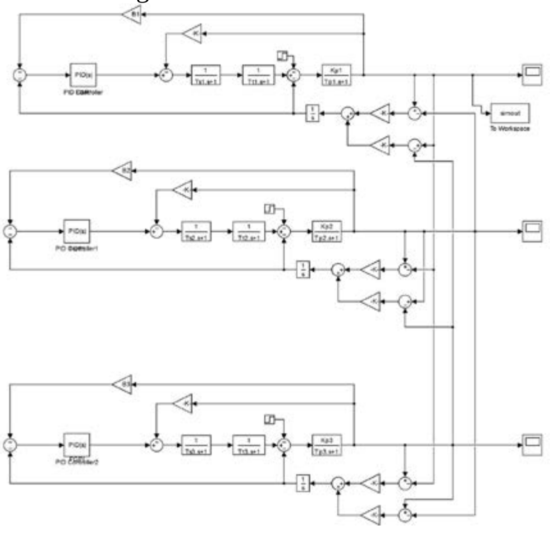


FIGURE 1

8. BACTERIA FORAGING OPTIMIZATION

As other swarm intelligence algorithms, Bacteria Foraging Optimization Algorithm (BFOA) is based on social and cooperative behaviors found in nature. The Bacterial Foraging Technique proposed by K.M.Passino [10]. This technique is based on the foraging behavior of the e.coli bacteria. The e.coli bacteria present in the human intestine. In fact, the way Bacteria look for regions of high levels of nutrients can be seen as an optimization process. Bacteria search for nutrients in a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemo taxis and key idea of BFOA is mimicking chemo tactic movement of virtual bacteria in the problem search space. They perform different functions such as chemo taxis, swarming, reproduction, and elimination and dispersal. In the chemo taxis a tumble followed by swim. Initially the e.coli bacteria measure the food concentration and then tumble to take a random direction and swim for a fixed distance. One step of chemo taxis is the combination of tumble and swim. Swarming means to work in a group. When one e.coli bacterium search nutrients, it can tell others in the group where the nutrients are. In reproduction stage least healthy bacteria will die out and the other healthiest bacteria will split into two bacteria. The no. of population is same in whole process. Furthermore, in elimination and dispersal step, events can occur such that all the bacteria in a region are killed or a group is dispersed into a new part of the environment.

9. ABBREVIATION:

The deviation in frequency: Del f

Frequency : f 1, f2, f3

Proportional Gain : Kp1, Kp2, Kp3

Governor Time Constant : Ts

Turbine Time Constant : Tt

Integral Gains: Ki 1, Ki 2, Ki 3

Bias Factor: Bi

Load Variation: del P

Regulation Parameter: R

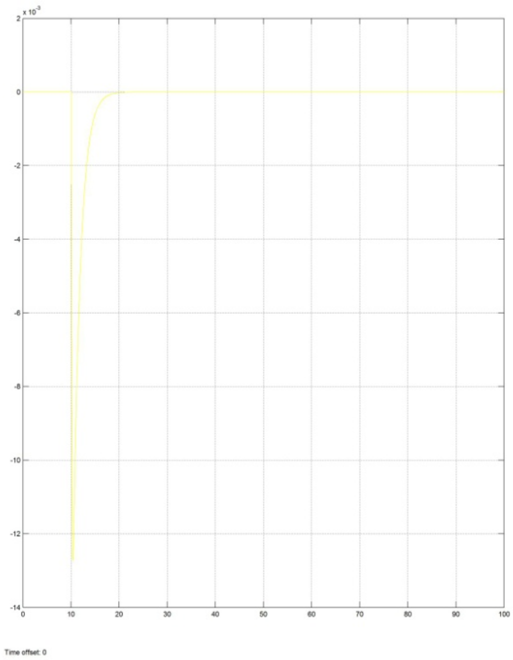
Area Control Error ACE

10. THE BFO ALGORITHM

```
Ne=20;
Nr=20;
Nc=20;
Np=20;
Ns=10;
D=3;
C=0.01;
Ped=0.9;   %   elimination   dispersion
probability

x=(rand(Np,D)-0.5)*60;
xp=x+80;
J=zeros(Np,1);
w1=0.5;
for k=1:Np

        Kp1=xp(1,1);
        Kp2=xp(1,2);
        Kp3=xp(1,3);

        J(k)=(w1*errorvariance+(1-
w1)*peakerror);%fitness functio
        for i=1:D-1

        J(k)=sum(100*(x(k,i+1)-
x(k,i)^2)^2+(x(k,i)-1)^2);
```

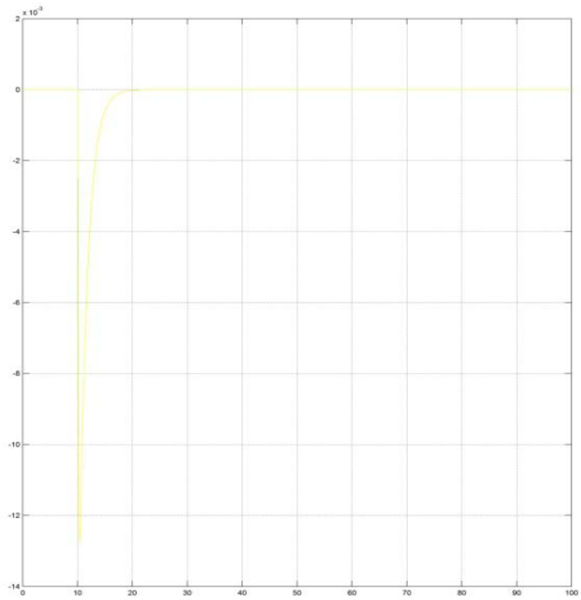
```
        end
end
Jlast=J;

for l=1:Ne
    for k=1:Nr
        Jchem=J;
        for j=1:Nc
            % Chemotaxis Loop %

            for i=1:Np
                del=(rand(1,D)-0.5)*2;

x(i,:)=x(i,:)+(C/sqrt(del*del'))*del;
                for d=1:D-1

J(i)=sum(100*(x(i,d+1)-
x(i,d)^2)^2+(x(i,d)-1)^2);
                end

                for m=1:Ns
                    if J(i)<Jlast(i)
                        Jlast(i)=J(i);

x(i,:)=x(i,:)+C*(del/sqrt(del*del'));
                        for d=1:D-1

J(i)=sum(100*(x(i,d+1)-
x(i,d)^2)^2+(x(i,d)-1)^2);
                        end
                    else
                        del=(rand(1,D)-
0.5)*2;

x(i,:)=x(i,:)+C*(del/sqrt(del*del'));
                        for d=1:D-1

J(i)=sum(100*(x(i,d+1)-
x(i,d)^2)^2+(x(i,d)-1)^2);
                        end
                    end
                end
            end

            Jchem=[Jchem J];
        end  % End of Chemotaxis %


            for i=1:Np

Jhealth(i)=sum(Jchem(i,:));  %  sum  of
cost  function  of  all  chemotactic  loops
for a given k & l
            end

[Jhealth1,I]=sort(Jhealth,'ascend');

x=[x(I(1:Np/2),:);x(I(1:Np/2),:)];

J=[J(I(1:Np/2),:);J(I(1:Np/2),:)];
            xmin=x(I(1),:);
    end
    Jmin(l)=min(J);
    % random elimination dispersion

  for i=1:Np
        r=rand;
        if r>=Ped
            x(i,:)=(rand(1,D)-0.5);
            for d=1:D-1

J(i)=sum(100*(x(i,d+1)-
x(i,d)^2)^2+(x(i,d)-1)^2);
            end
        end
    end

end
plot(Jmin);
```

Frequency deviation in area1 with PID controller (plot1)



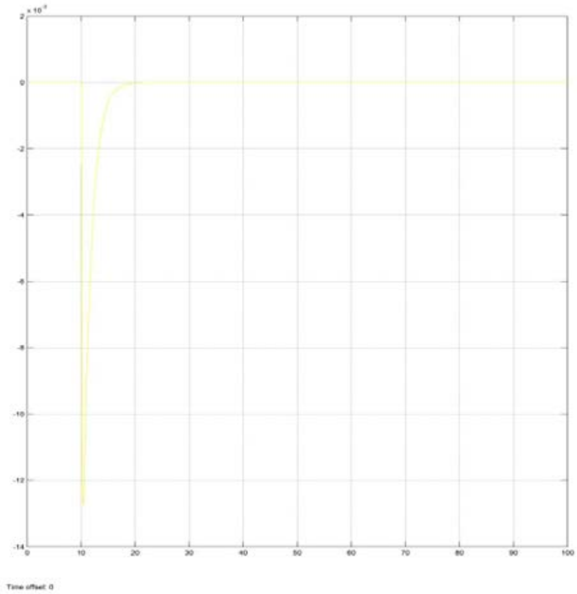
Plot1

Frequency deviation in area 2 with PID controller (plot2)



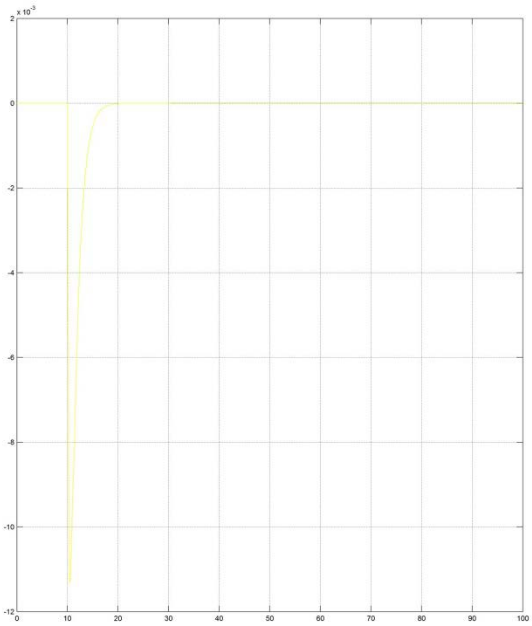
Plot 2

Frequency deviation in area 3 with PID controller (plot3)



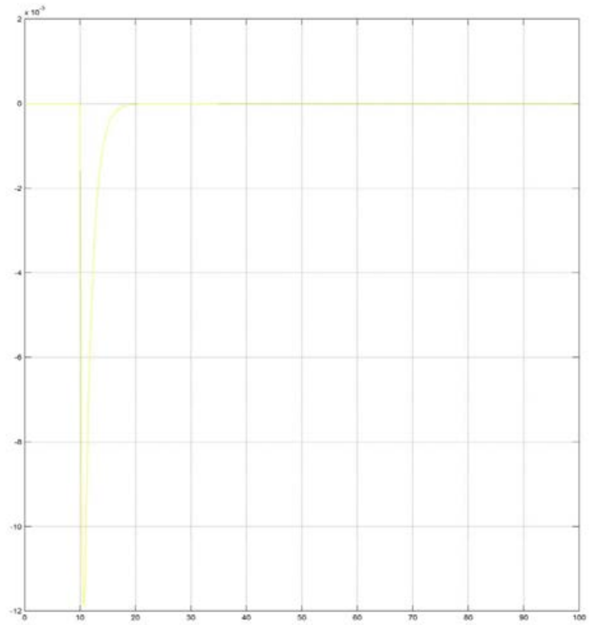
Plot3

Frequency deviation in Area 1 using BFO (plot4)



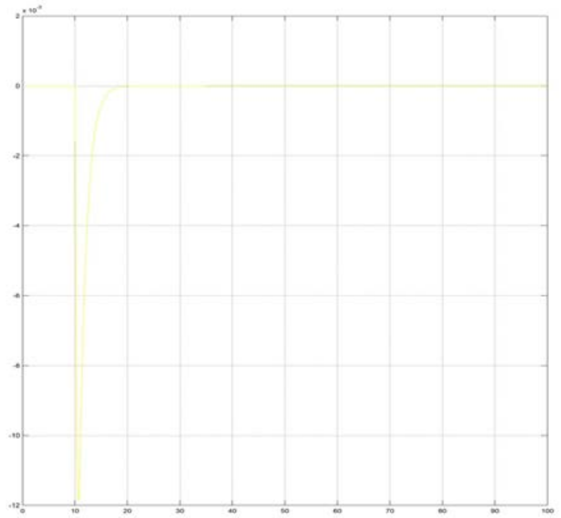
Plot4

Frequency deviation in Area 2 using BFO (plot5)



Plot5

Frequency deviation in Area 3 using BFO(Plot6)



Plot6

11. OBSERVATIONS:

TABLE1.

	Settling time			Peak overshoot		
	Del f1	*Del f2*	*Del f3*	*Del f1*	*Delf2*	*Del f3*
With PID controller	23	23	23	12.4	12.4	12.5
With BFO	20	20	20	11.8	11.8	11.9

TABLE2.

	Comparison of Kp		
	Kp1	*Kp2*	*Kp3*
With PID controller	120	120	120
With BFOA(System generated)	91.33	58.87	53.32

12. CONCLUSION

It has been observed that BFOA is faster optimization method than other conventional methods like PID. With the use of BFOA peak overshoot and settling time has been reduced (table1) and it gives the optimal values of Kp (table2).

13. FUTURE SCOPE

Bacterial Foraging Algorithms is better method for Automatic Load frequency control than other conventional method and it can be further extended to 4 area or multi area interconnected system. Bacterial Foraging optimization algorithms have been successfully used to solve numerous different problems. In future, BFOs will prove to be a general purpose powerful heuristic method for solving wide engineering and scientific problems.

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