

Optimization of Load Frequency Control using Nature Inspired Algorithm



Kandukuri Abhishek, P. Sri Vidya Devi

Abstract: This paper describes about load frequency control problem in power systems by using multi-verse optimization algorithm (MVO). This paper compares the controlling of LFC with PID and PID+MVO controllers. In this paper four area hydrothermal networks was represented. MVO algorithm was introduced in this paper for tuning the secondary controllers. The concept of MVO is runs on white hole, black hole and warm hole. Inflation rates of universe can be calculated and implemented in PID. This paper was implemented in simulator (MATLAB/SIMULINK) software.

I. INTRODUCTION

Nature has been the principle motivation for most of the based population stochastic optimization strategies. This optimization procedure is started by considering some set of variables random. Load demand in modern power systems increases rapidly to keep synchronization between control area and consumers, frequency was predefined. Abnormal variations in frequency may cause huge damage to network. To overcome this problem Load frequency controller (LFC) is used, in which in monitors entire power system and regulates according to variations. LFC also regulates the governor values for steam flow. Load frequency controlling by multi-area network was discussed along with its implementation. Main motive in LFC to compensate the area control error (ACE), to minimize this ACE we need to tune the secondary controller. Integral square errors (ISE), Integral time square error (ITSE), Integral absolute error (IAE) were used to define fitness function for tuning controllers. For the first time, Integral Controller (I) was used for in Load frequency controlling. Stabilization and nullification of error was not efficient [1]. PI [2] controller was implemented to overcome drawback of Integral (I) Controller. Stability was improved for two-area control network. But it is showing various fluctuations at the time of sudden load changing and dynamics in boiler [2]. PID [3] controller was introduced in LFC. By using K_p , K_i and K_d values the system tuned very well. Because of giving predetermined values, the controller was not able to perform very well for sudden load changes. IDD Controller was introduced to nullify the disadvantages of Integral controller (I), Proportional-Integral (PI) and PID Controllers.

According to For theoretical strategies these three controllers showing various characteristics but while coming to practical strategies these are showing similar results. Even these similar results were not much responsive and efficient. Revised Manuscript Received on July 22, 2019. For sudden load changes. For practical and theoretical strategies IDD is having more response to sudden changes in current as compare with these three controllers. However there is need of intelligent controllers, which lead to use Fuzzy Logic Controller (FLC) for, much supportive at the time of non-linearities. Then combination of PI and Fuzzy controller was observed in . These are showing good response as compare with conventional controllers. Neural networks and neural networks with fuzzy controller were also observed in [4], but because of giving predetermined weighted values and rules, these controllers can work according to their boundary limits only. Genetics Algorithm (GAs) [1] use the existence of the fitting function nature so as to choose the best arrangements and after that consolidate them dependent on their production of chromosomes. Where Particle Swarm Optimization (PSO) [5] was taken from individual behavior thinking of birds when flying, as to find the best position of their particle. Gravitational Search algorithms (GSA) [6] uses Newtons law of motions to move search agents. GA and PSO [7] are having less sensible for local parameter changing; to overcome this technique Bacterial foraging optimization technique was introduced [8] Sakia, L.C. have assigned PID double-derivative controller (PID + DD) for solutions of Frequency Control problem. this has been limited study to three areas thermal power plant only., Guha. [9] Internal model controller (IMC) philosophy says that for every controlling problem control system should be employed internally or externally, then perfect control is theoretically possible. [10] Tripathy, S.C., developed a sliding mode controller in which applies not continuous signal the sliding force applied and move along a cross-section of the system's normal behavior. Tripathy, S.C have exam the problem of the inter linked system of power system there are different methods to identify the describing function used for linear approximate. Recently, cuckoo algorithm search (CSA) has introduced to tuning of the PI-controller gains different thermal power plant. Differentials evolution (DE) has very simple structure and can be effortlessly applied to LFC problem. Besides these, moth-flame optimization. So to show the PID + DD controllers for the power system large area non-linear connected power systems, in future surveys is required. the time-variation of different load in power System, the control point of operation will be changed minute to minute. genetic algorithm (GA) is applied to frequency problems, algorithm based on the principles of Genetics and Natural Selection.

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internal model controller TLBO algorithm is another nature inspired algorithm it gives best results but the security features between the teacher and the learner is very less. The different types of algorithm or controllers are not providing the satisfactory results so we have gone for other algorithms or controllers.

Likewise, a population based algorithm was developed and it is called as MVO. This MVO evolved on the theory of MVO physics. Three major concepts (White hole, black hole and worm hole) are mathematically expressed. Fitness functions of particular solution can be found. The best function was implemented in to LFC network, in order to make it stable from all deviations.

II. PROPOSED METHOD:

Hydro thermal plant is having its own transfer functions. In this paper four-area hydro-thermal plant was introduced. Four area networks having maximum six tie lines. In the given figure every area has to connect to all other areas.

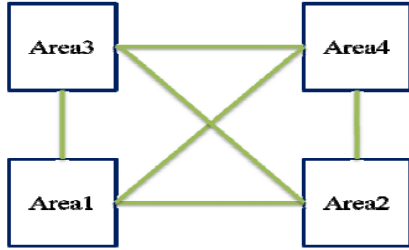


Fig1: Shows the Over view of a Four-Area Interconnected Power System

These frequency variations may cause, alter the power system stability. Changes in tie-line and its deviations in frequency were represented as shown in figure. These deviations can be calculated from feedback procedures. It is like Power system having more number of non-linear parts. These are connected to each other by tie lines. From the controller settings, we have to calculate the damping values and settling times of signals.

$$z = Dg + Ee$$

$$V = Fe$$

D- matrix System, E-matrix input, e-state, g-control matrix and C-output matrix.

$$g = [g_1 g_2 g_3 g_4]^T$$

$$V = [v_1 v_2 v_3 v_4]^T = [\Delta f_1 \Delta f_2 \Delta f_3 \Delta f_4]^T$$

$$z = [\Delta f_1 \Delta P_{T1} \Delta P_{G1} \Delta P_{c1} \Delta P_{tie1} \Delta f_2 \Delta P_{T2} \Delta P_{G2} \Delta P_{c2} \Delta P_{tie2} \Delta f_3 \Delta P_{T3} \Delta P_{G3} \Delta P_{c3} \Delta P_{tie3} \Delta f_4 \Delta P_{T4} \Delta P_{G4} \Delta P_{c4} \Delta P_{tie4}]^T$$

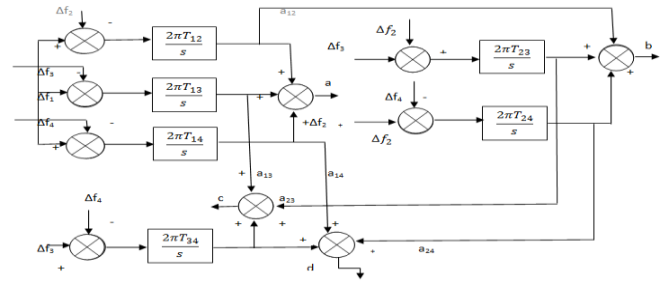


Fig.2 shows the blocks for derivative frequency

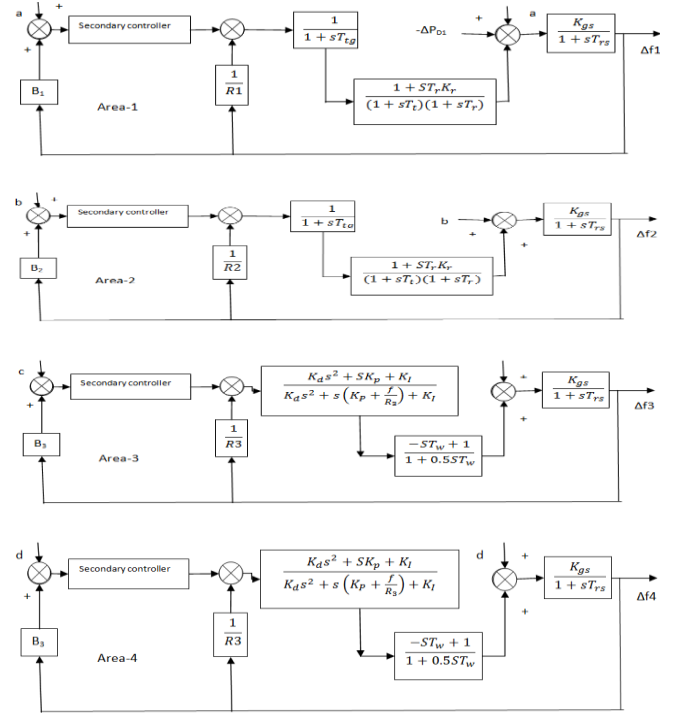


Fig.3 shows the four-area control network.

In put value can be given in area control error (ACE_i) format, suffix 'i' represents the value of control areas i.e. 1,2,3,4.

$$ACE_i = E_i \Delta f_i + \Delta P_{tie\ ij}$$

Multi-Verse Optimizer:

The term multi-verse stands for opposite of universe and it's existence. It depends on three main concepts like: White hole, Black hole and worm hole. According to this method, there are more number of universe and every universe is having its own inflation rate.

MVO algorithm:

This algorithm corresponds two phases like: exploration versus exploitation. We need to explore the search spaces by MVO. We can utilize the concept of white gives the processing signal output and black hole for input which is to explore. In spite, by using exploiting the search spaces. We should assume, that each solution is analogous to universe and each variable as one object. We assign inflation rate to each solution, which is proportional to each fitness function, time can be used instead of iteration. In optimization, certain rules can be followed as discussed below.

1. As the number of inflation rate increases, probability of white holes can be increased.
2. As the number of inflation rate increases, probability of black hole rate can be reduced.
3. Objects can be tend to send to white holes, if inflation rate is more.
4. Objects can be moved toward warm hole for regardless inflation rate.

We assume, objects with high inflation rate as white holes and objects with less inflation rate as black holes. This universe, send objects from white holes to black holes. In order to calculate mathematical equation for exchange of objects roulette wheel mechanism is utilized.

$$U = \begin{bmatrix} x^1_1 & x^2_1 & \cdot & \cdot & \cdot & x^d_1 \\ x^1_2 & x^2_2 & \cdot & \cdot & \cdot & x^d_2 \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot & \cdot & \cdot \\ x^1_n & x^2_n & \cdot & \cdot & \cdot & x^d_n \end{bmatrix}$$

d represent no of the variables, **n** represent the number of universe

$$z_i^j = \begin{cases} x_k^j & \text{.....} r1 < NI(Ui) \\ x_i^j & \text{.....} r1 > NI(Ui) \end{cases}$$

x_j indicates the j^{th} parameter of universe, z_i^j the k^{th} parameter of 1^{th} universe and $r2, r5$ and $r6$ are random numbers in $[1, 2]$ for each object indexed by ifor each object indexed $r_2 = \text{random}([1, 2]);$

NI=theuniversesNormalize
inflation rate(fitness)

SU= Universes Sorted

each universes indexs by l

Black_hole=X;

for each object indexed

$r_1 = \text{random}([1, 2])$

if $r_1 = NI(Ui)$

$U(\text{Black_hole_index}, k) =$
 $SU(\text{White_hole_index}, j);$

White_hole_index=Roul
ette Wheel Selection(-NI);

by i

endif

end for

end for

Lower inflations rate means having more probability to send objects for exchange. To maximize the problems -NI has to shift towards +NI. For pseudo codes and mathematical formula there exists two main coefficients herein: Distance of travelling rate (TDR) and existence of wormhole probability (WEP).

$$WEP = \text{minimum} + i * \left(\frac{\text{max} - \text{min}}{L} \right)$$

Where... i=present iteration.

min=minimum (0.21 as per paper)

Max=maximum (1 as per paper)

L=maximum iteration.

$$TDR = I - \frac{i^{\frac{1}{P}}}{L^{\frac{1}{P}}}$$

P=exploration accuracy(6 as per
basepaper)

If we want to make some local changes and to increase inflation rate with worm holes. Following equation has to be considered

$$z_{li}^k = \begin{cases} x_k + TDR * ((ub_{u_k} - ib_k) * r6 + ib_k) & .r5 < 0.5 \\ x_k - TDR * ((ub_{u_k} - ib_k) * r6 + ib_k) & .r5 \geq 0.5 \end{cases}$$

Above two operation can be done for $r2 < WEP$ and below one is for $r2 \geq 0.5$

The x_j indicates, k^{th} parameter of best universe established so far,

the x_l^k indicates, k^{th} parameter of 1^{th}

universe and $r5, r6$ and $r2$ are numbers random in $[1, 2]$

for I index for each object

for j index for each object

$r_2 = \text{randomly}([1, 2]);$

if $r_2 < \text{Warm_hole_probability}$

$r_3 = \text{randomly}([1, 2]);$

$r_4 = \text{randomly}([1, 2]);$

if $r_5 < 0.5$

```

U(I,j)=Best_Universe(j)+ distance_travelling_
      rate*((Ubuk)-(lbuk)*r4+lb(m));
else
(I,j)=Best_Universe(j)+Travellin
g_distanc e_rate*((Ubuk)-
(lbuk)*r6+lbu(k));
Endif
endif
end for
end for

```

Computational complexity is works on number of iteration, number of universes and mechanism of roulette wheel. Sorting universes is done in every iteration, for this Quick sort algorithm is implemented. This has the complexity of $H(n \log n)$ and $H(n^2)$ is best and worst case.

```

H(MVO)=H(I(H(Quicksort)+n*o*(H(roulette
wheel))))
H(MVO)=H(I(n^2+n*o*log(n)))
Where n= universe count
I=maximum iterations,
o=number of objects.

```

III. RESULTS AND DISCUSSION

This part compares the performance and feasibility of two controllers. Random Load pattern was applied to calculate the feasibility of controller. Below figure shows the comparison of PID and Fuzzy controller application along with MVO.

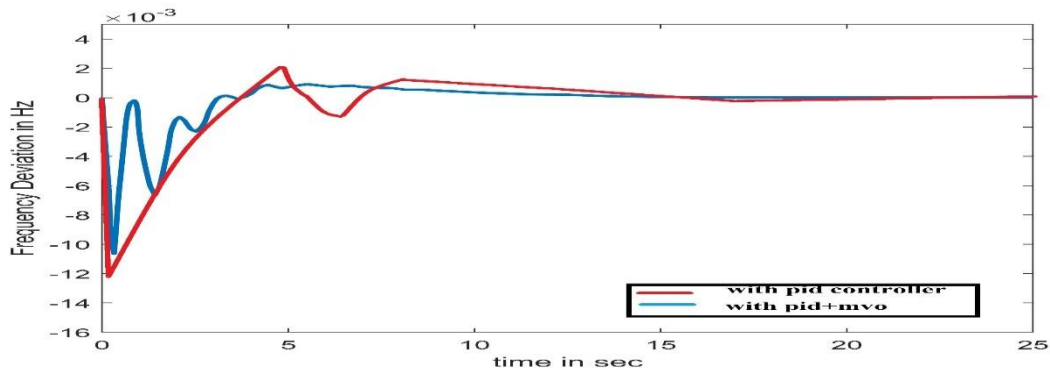


Fig.4 this is frequency deviation for Area 1 (Δf_1).

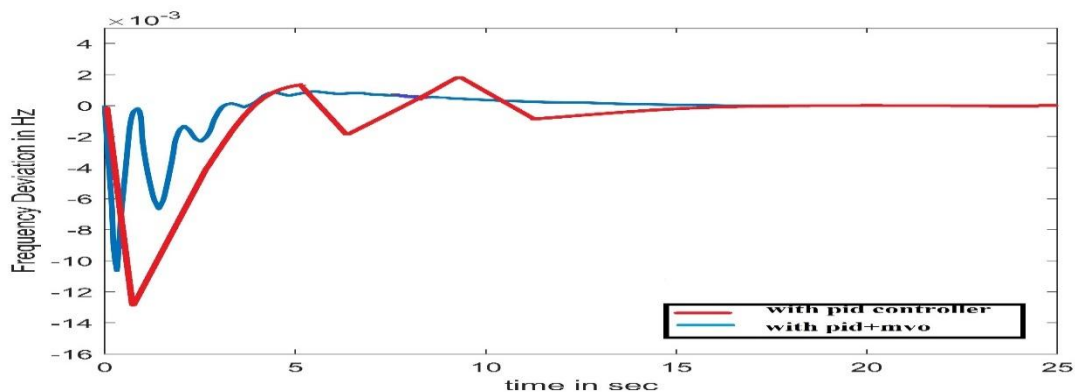


Fig.5 This is frequency deviation for Area 2 (Δf_2).

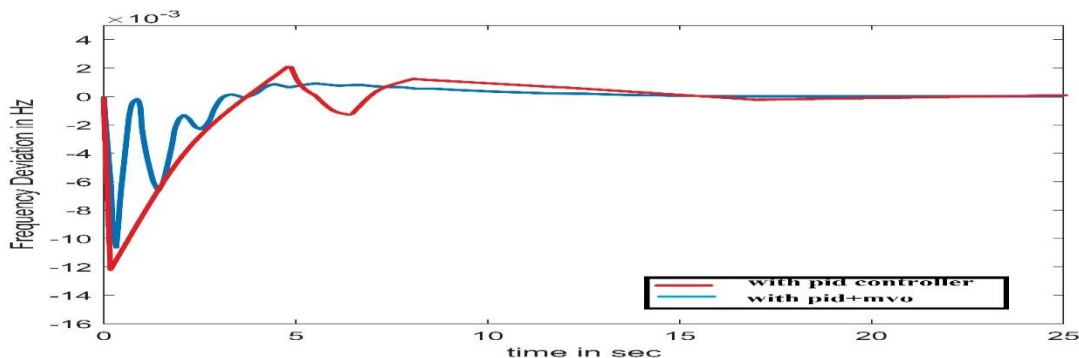


Fig.6 this is frequency deviation for Area 3 (Δf_3).

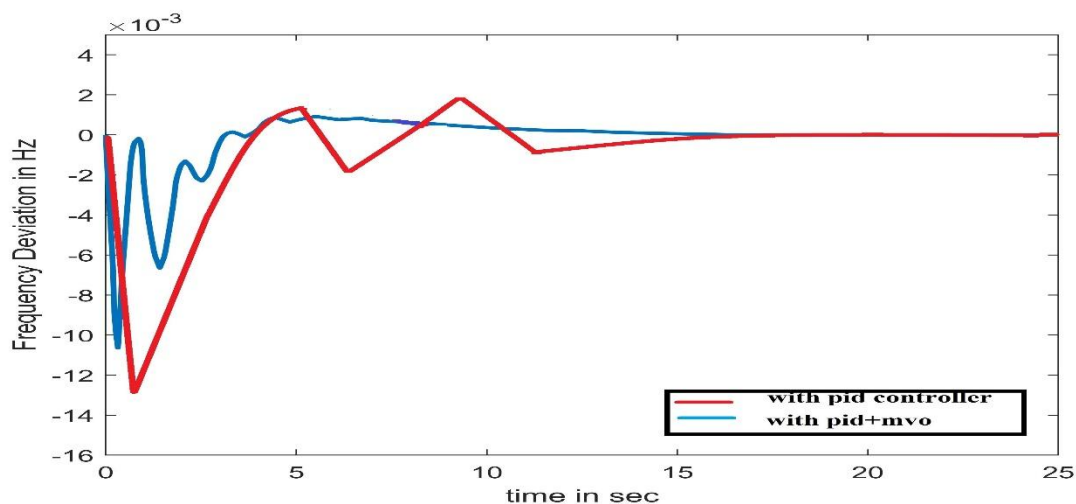


Fig.7. change of frequency deviation for Area 4 (Δf_4).

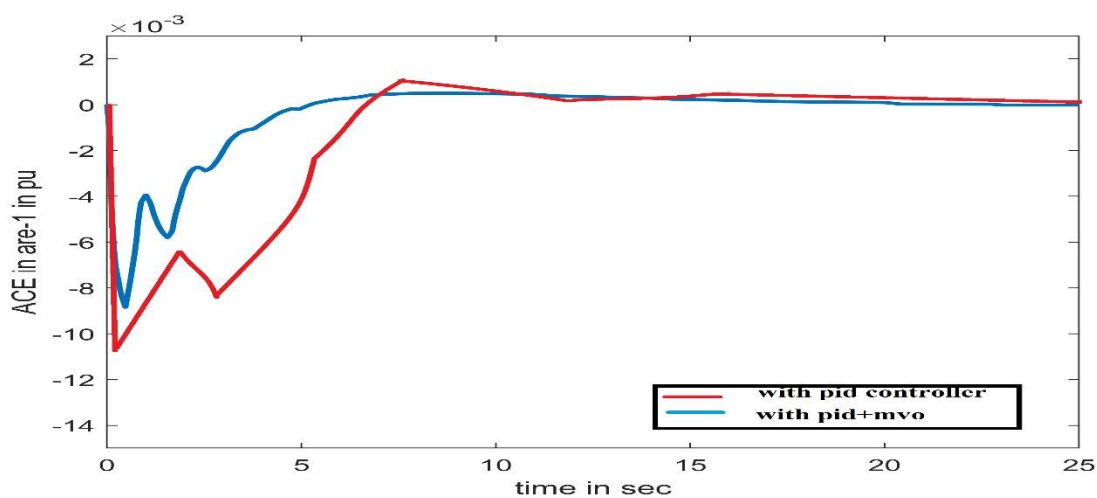


Fig.8 change of tie-line frequency for area1-2.

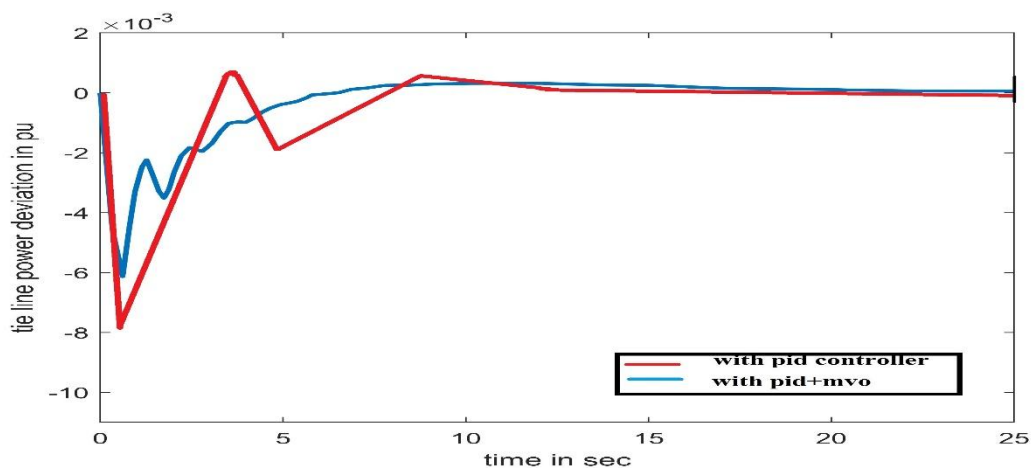


Fig.9 tie-line frequency for area 1-3.

Table Comparison table of system performance with MVO with PID controller

Specification		Undershoot					
Settling time		Δf_1	Δf_2	Δf_3	Δf_4	$\Delta P_{tie,th-th}$	
$\Delta P_{tie,th-hy}$	Δf_1		Δf_2	Δf_3	Δf_4		
$\Delta P_{tie,th-th}$	$\Delta P_{tie,th-hy}$						
PID	12.1	13.2	12.4	13.5	7.9	12.3	18
17	17.5	18.2	65	70			
MVO+pid	9.3	9.8	10.1	10.3	6.0	8.2	
10.9	10.8	10.2	10.5	13.2	14.9		

IV. CONCLUSION

Load frequency controlling for multi area for all thermal plants were observed with MVO+ PID and PID controller was observed. From above given figures we can observe that Plots with other controller are fluctuating more than Plots with pid controller.(other controller plots takes more time for settling time than pid controller plots.So, pid+mvo controller is operating more efficient than PI controller while applying MVO.

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