International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-9 Issue-1, May 2020

Design of Fractional Order PID (FOPID)for Load Frequency Control Via IMC & Grey Wolf Algorithm (GWO), for a Non-Reheated Power System by Comparing with the Big Bang Big Crunch (BBBC) Optimization

Bhavandla Bhanupradeep, Dola Gobinda Padhan

Abstract: In this paper work deals about the application of Grey Wolf Optimizer (GWO) for optimization of fractional order PID (FOPID) controlling device to the frequency disturbance, of system load in the one (or) single area non re-heated electrical system and also comparison to the non re-heated BBBC optimization outputs. In this BBBC optimization we have the two bounding cases (low & upper), they are before and after the perturbation cases. And also we observed that the BBBC output responses. After finding the BBBC outputs we observed that the settling time value of load frequency of BBBC is more when compared with the GWO. This problem is resolved by designing of FOPID via GWO algorithm. The Grey Wolf Optimization is well known meta-heuristic algorithm and has been previously used for optimization of various conventional PID and FOPID controllers. In this paper the GWO is used for optimization of FOPID controller to the load frequency variation in the electrical system for non reheated turbine electrical system .the execution outputs of the proposed controlled method also validated to the other existing techniques.

Keywords: Design of FOPID of frequency variation control in particular load system, for one area power system in non reheated turbine case. ; Load frequency control (LFC); FOPID controller; and BBBC, Grey Wolf Optimizer (GWO

I. INTRODUCTION

The executed outputs of major electrical system is under goes degradation in power quality obtain because of the load changes in the electrical power system reflects the variation of the electric power flow between in one line to nearly connected another lines of the system.as well as frequency of particular system area. The problem tells us to need of frequency controlling device to resolve the variations in the system load ,output values uncertainties and also control to the unwanted electric energy flowing among inter-connected electrical system areas. These frequency controlling device of the system load useful for the minimization of load variation issue, robustness issues in the power system. Different newest controlled techniques are applied, they are optimal control , sliding mode control , PID control , internal controlled scheme, etc. all these methods reduce the variation in the electric system load values. Now, present days method of minor calculus method have proof of most successful in electric system world. In the FOPID controlling device provides extra benefits in the designing electric power system. They are gives the five controlled values they are k_P, k_I, k_D, λ, μ in place of three parameter values.

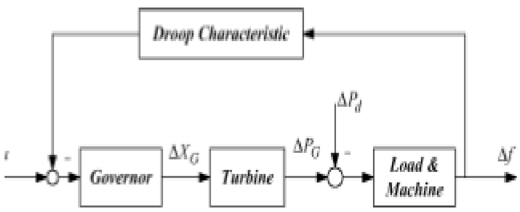
Revised Manuscript Received on May 15, 2020.

Bhavandla Bhanupradeep, Department of EEE, Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad, India.

Dr. Dola Gobinda Padhan, Professor, Department of EEE, Gokaraju Rangaraju Institute of Engineering & Technology, Hyderabad, India.

OVERVIEW ABOUT LFC:

Load frequency control is nothing but suddenly load changes in the particular area when abnormal conditions occur in the system. The controlled device maintaining is most important to the electrical system. In previous years most of theories explained about load frequency control in the electrical system. Present coloum electric factories are changed to transformed to the re-designing manner.The load frequency controlled issue in the electric power system needs the not only frequency variation of every area compulsory regain their original point but also regain the tie-line energy flow need to regain their pre defined values. If the electric system values are changes then its re-construction is difficult to the entire electric system when the system is under processing by using PID model controllers.In this paper we are controlling such problems by designing of FOPID for better output frequency responses.



Figuer.1. one area electric power system.

1.2. INTRODUCTION OF FOPID:

In present days, the fractional order controller has been very common for various real-world application problems in each field of engineering and also industrial applications. The first FOPID controllers as the command-rousted order system it is a non- entire (CRONE) controller. He implemented this controller in different field of control application. The success of FOPID controller is due to its extra degree of freedom which provides additional support to maintain a proper balance between the time-domain specifications of the system. Moreover, performance of FOPID controller is also proved better for many other practical systems.

$$c(s) = K_p + \frac{K_i}{s^{\lambda}} + K_d . S^{\mu} \qquad (1)$$

Above equation tells where k_P, k_I, k_D, , λ , µ are five tuning parameters values of FO-PID . By using FOPID controller we can found the five parameters of the single-area electric power system for better load frequency controlling device via grey wolf algorithm.

II. STATEMENTS OF PROBLEM:

The electric power system is a major sector system having the difficultly in unlinear dynamics in the nature. Whatever , for small changes in the load variation , then it reflects the variations in the linear model of the system, liberalized in the operated point. The multi- level electric power system of LFC designing having a governor $G_g(s)$ un re-heated turbine $G_t(s)$, load & machine device $G_p(s)$, drooping characteristics of the system. Each and every component values of system dynamics are listed below:

$$G_g(s) = \frac{1+0}{1(1+T_g s)} \qquad (1)$$

$$G_t(s) = \frac{1+0}{1+T_t s} \qquad (2)$$

$$G_p(s) = \frac{K}{1+T_p s} \qquad (3)$$

In the table 1 shows the nomenclature of used symbols. Characterization of system model is explained by the given below transfer function:

$$\Delta F(s) = T_u(s)\Delta u(s) + T_d(s)\Delta P_d(s) (4)$$

Above formula tells us to LFC is a firstly disturbed rejected issue in the system, and our major work is to develop robusted FOPID controlling device of a single area electric power system. By using this controller we want to minimize the load variations on the ΔF is minimum value and by using below formula design of FOPID controlled device.

$$c(s) = k_p + \frac{K_i}{s^{\lambda}} + K_d . S^{\mu} \qquad (5)$$

Here are k_P, k_I, k_D denotes as proportional gain, integral gain, the derivative gain respectively. λ , µ denotes the fractional integral, derivative terms respectviely .

Table1. Nomenclature: Power system parameters.

Parameters	Abbreviations
ΔF	frequency variation change in the system (Hz).
k	Gain of the power system.
∂P_d	Variation in the load (p.u.MW).
r	Governor speed variation according to work (Hz/p.u.MW).
T_g	time constant of the governer (s).
T_p	time constant of electric power system(s).
T_t	time constant of the system (s).

III. PROPOSED APPROACH OF THE GWO-FOPID:

The proposed method is divided to mainly two modes of operation , in the mode 1 tells us to the designing of the PID-IMC controller of the electrical power system. In mode 2 we utilizes the GWO algoritham to developes the optimal FOPID controlled device by helpful of PID parameter values founded in the mode1 it tells us bounding solutions area. The route of developed calculations of a executed method is given below.

3.1. INTERNAL CONTROLLED METHOD:

From (1)-(4) tells us to the single area electrical power 3rd order system. This 3rd system can be reduced to the 2nd order system before the IMC approachment. In this work this order decrement is via GWO algorithm. Because it is easy to knowing the concept and also this 2nd order method reflects the original system value. Reduced order method formula is given below.

$$G_R(S) = \frac{a_0 + a_1 s}{b_0 s^2 + b_1 s + b_2} \qquad (6)$$

Where a_j, j = 0 , 1 & b_i, i = 0, 1 ,2

Coefficients to S, & b_i > 1.

The load frequency variation control problems we identified the decreased order method occuerd via GWO is gives us to the non –minimum phase value system for that we need the $a_1 \leq 0$& $a_1 \geq 0$.

The exact process is need to apply for the GWO algorithm of the system.Then from (6) can be re-written as

$$G_R(S) = \frac{a_0(1+a_2 s)}{b_0 s^2 + b_1 s + b_2} \qquad (7)$$

Where $a_2 = \frac{a_1}{a_0} < 1$

After occurring of decreased order method then we execute the IMC method to LF control issue

.Diagram. 2 shows block diagram of the basic IMC control .

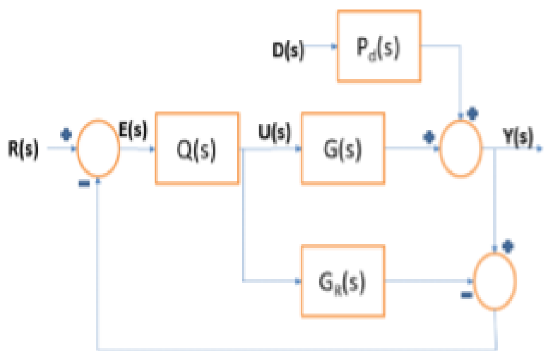


Figure.2. Basic IMC control scheme.

The plant model is factorized as

$$G_R(s) = G_{R-}(s) G_{R+}(s) \qquad (8)$$

Where $G_{R-}(s)$ and $G_{R+}(s)$ represent the minimum and non-minimum phase parts respectively.

$$G_{R-}(s) = \frac{a_0}{b_0 s^2 + b_1 s + b_2} \qquad (9)$$

$$G_{R+}(s) = (1 + a_2 s) \qquad (10)$$

Further next step formula is written below

$$f(S) = \frac{1}{(1+\delta s)^K} \qquad (11)$$

Here, δ is intuitively modulated value. K represents the IMC controlled device. Here k = 1.

End of the operating work IMC controlled device gives the below formula

$$Q(s) = f(S)G_R^{-1}(s) = \frac{b_0 s^2 + b_1 s + b_2}{a_0(1+\delta s)} \quad (12)$$

PID controller formula in the feed -back mode is writes below

$$C_{IMC}(s) = \frac{Q_s}{1 - G_R(s)\,Q(s)} \quad (13)$$

The replacement of these values in $G_R(s)$ & Q(s) through equations (7) ,(12).

$$C_{IMC}(s) = \frac{b_1}{a_0\delta - a_1} + \frac{b_2}{a_0\delta - a_1}\frac{1}{s} + \frac{b_0}{a_0\delta - a_1}s \quad (14)$$

Formula (16) is again wrote by

$$C_{IMC}(s) = k_p + k_i\frac{1}{s} + K_d s \quad (15)$$

Where $K_p = \frac{b_1}{a_0\delta - a_1}$, $K_i = \frac{b_2}{a_0\delta - a_1}$, & $K_d = \frac{b_0}{a_0\delta - a_1}$.

Now finally we occurred values to the PID-IMC control scheme. Then further step is the occurred values is useful to found the solution of FO-PID via GWO algorithm technique.

3.2 BB-BC ALGORITHM:

From This optimization technique , Mainly it has two phases BB phase & BC phase. BB phase will tells us solution of the population evaluated in irregularly in a distributed area.

BC phase tells us single representative solution is nothing but center of mass solution. This optimization technique starts real-power distributed in the atmosphere. This BB phase reflects the searching area procedure and BC phase represents the better outputs of the system.

This procedure for BB-BC algorithm to find solution of unwanted load frequency in one area non re-heated electric power system.

Step 1: initialize this BBBC parameters like N, ψ, matrix & iteration and using the below formulas we can found the lower bound & upper bound parameters .

Where k_p, k_i, k_d are PID parameter values from equation (15). λ and μ ∈ (0,2). If λ, μ ≥ 0,

$$L = [p^{-1}k_p,\ p^{-1}k_i,\ p^{-1}k_d,\ 0\ ,0]$$
$$U = [pk_p, pk_i, pk_d, 2\ ,2]$$

Step 2: it generates N candidate solution is called Big Bang Phase (BBP).

$x_i = L + (U - L)oR \qquad i = 1,2,\dots\dots N$

Where x_i = vector , i = candidate iteration.

Step 3 & step 4 : In the 3rd stage tells us the optimized mathematical matrix of the number of students results, and in the 4th stage tells us the order of the fitnessed results with their magnitude values.

.step 5 : in this method tells us to number of newly presented candidates solution in searching area according to the origin mass developed in the last stage. By useful formula written below

$$x_i^{iter+1} = C^{iter} + \frac{r_i \varphi(U-L)}{iter+1}$$

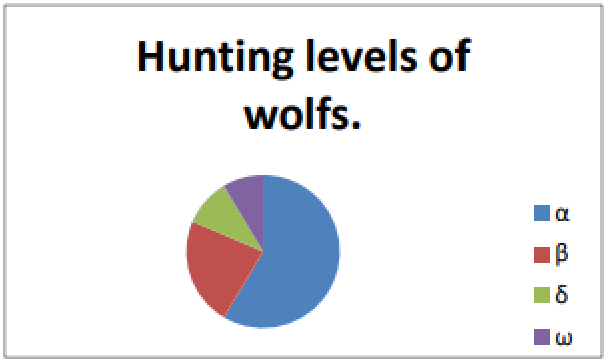
Step 6: In this stage fitness matrix set values of newly generated candidate solutions, and repeated the process until final value occurred.

The BBBC algorithm gives large settling time value when controlling load frequency in non re-heated single area power system when control parameter values changes to +50% means upper bound & -50% lower bound parameters. This problem is solved by using grey wolf optimization control scheme to control load frequency disturbance problem by using below procedure.

3.2.1 GREY WOLF (GWO) OPTIMIZATION ALGORITHAM:

GWO is a one of the optimized method to development of proportional , integrative , derivative controller.The GWO algorithm is useful to the checking the behavior of wolfs group. according to analysis of making between potential solution of the problem, number of wolfs chaseing the prey. Below diagram having the stages of wolfs a/c to the their hunting process.

3.2.2. GWO LEVELS:



1. Alphas (α):

it is gives the better solution when compared to remaining wolfs. These are the head of the total wolfs.

.2. Betas (β): these are gives the 2nd better population solution of the total wolfs. It is subordinate the alphas.

3. Delta (δ): these are represents third order wolfs and subordinates to the beta.

4. Omegas (ω): these are subordinates to all the rest of population solutions.

3.2.3. MATHEMATICAL MODEL:

In the modeling, the GWO Algorithm resembles the leadership hierarchy and hunted system of the wolfs .

A. Social point view:

The model of social view of hierarchy is carries the alpha (α) gives us best solution follows by beta (β) & delta (δ) & omega (ω) .

B. En-circling prey:

The Grey wolves rounded the prey and chases them up to the prey stops at un movement stage means ,prey stops stand still condition. The given below formulas tells the behavior of the wolfs.

$\vec{D} = |\vec{C}.\vec{x_p}(t) - \vec{x}(t)| \qquad (16)$

$\vec{x}(t+1) = |\vec{x_p}(t) - \vec{A}.\vec{D}| \qquad (17)$

Where t means iteration number, $\vec{A}$ & $\vec{c}$ means co-efficient vectors, $\vec{x}_p$ meaning of the position vector of the prey & $\vec{x}$ stands for position vector of the Grey Wolfs. $\vec{A}$ & $\vec{c}$ vector calculation as given below,

$\vec{A} = 2(\vec{a}.\vec{r_1} - \vec{a})$ & $\vec{C} = 2.\vec{r_2}(1) \qquad (18)$

Here contents of $\vec{a}$ are linearly dropped from 2 to 0 in the course of iteration & $\vec{r_1}$, $\vec{r_2}$ are randomly developed vectors in [0,1]. From above mentioned equations, the Grey Wolf is capable of upgrading the its position of the (X, Y) depends on the position of the prey (X*, Y*).and also develops the new position is based on the current position adjustment of the values of $\vec{A}$ & $\vec{c}$ vectors. The movement of Grey Wolves having like squares and circles.

C. Hunting:

The hunting process will be handled through the alphas. grey wolves is majorly advised by the alpha.

The following below equations are useful for the grey wolf optimization for finding the load frequency problem for non reheated power system.

$$\overrightarrow{D_{\alpha 1}} = |\overrightarrow{C_1} . \overrightarrow{x_{1\alpha}}(t) - \vec{x}(t)|$$

$$\overrightarrow{D_{\beta 1}} = |\overrightarrow{C_2} . \overrightarrow{x_{\beta 1}}(t) - \vec{x}(t)|$$

$$\overrightarrow{D_{\delta 1}} = |\overrightarrow{C_3} . \overrightarrow{x_{\delta 1}}(t) - \vec{x}(t)|$$

$$\overrightarrow{x_1} = \overrightarrow{x_{\alpha 1}} - \overrightarrow{A_1} . \overrightarrow{D_{\alpha 1}}$$

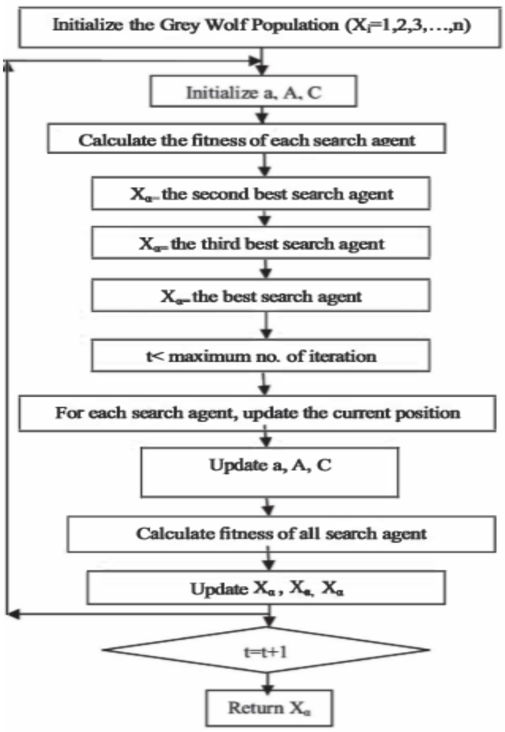
$$\overrightarrow{x_2} = \overrightarrow{x_{\beta 1}} - \overrightarrow{A_2} . \overrightarrow{D_{\beta 1}}$$

$$\overrightarrow{x_3} = \overrightarrow{x_{\delta 1}} - \overrightarrow{A_3} . \overrightarrow{D_{\delta 1}}$$

$$\vec{x}(t+1) = \frac{\overrightarrow{x_1} + \overrightarrow{x_2} + \vec{x}}{3}$$

D. Attacking the prey :

This mode is activated after the hunting is completes when prey at stand still condition.Below shows the flow chart diagram for grey wolf optimization diagram for finding procedure of the better frequency response in single area non-reheated turbine power system.



Figuer.3. Flow chart for GWO algorithm.

IV. NUMERICAL STUDY:

From figure 1 we observed that the non re-heated turbine single area power ststem and drooping characteristics of the system. this simulation is developed in the matlab software .the useful parameter values of LFC are listed below. they are K = 120, T_g = 0.081, T_p = 21 , , T_t = 0.4, R = 2.41By using the above values, the plant model in the transfer function form is written in the below

$$G(s) = \frac{250}{s^3 + 15.88s^2 + 42.45s + 106}$$

The con-ventionalized IMC-PID control device is obtaines by using the equations from (7) – (15) and these are gives the typical parameter values of the GWO for developing the FOPID controllers In this the required K_p, K_i, K_d, λ and μ values are found by using formulas written in above grey wolf optimization chapter by solving through the IMC-PID equations. These equations are resolved into two degree equations and this equations are found transfer function values. These control parameter values are substitute in the PID control diagram designed in the MATLAB software 2016a. In the GWO optimization technique is gives better frequency response settling time value. It is also reduce the IAE, ITAE, STD errors in the single area non-reheated power system when compared with the BBBC optimization technique. GWO is also gives the better response values after perturbation case means after changing the control parameter values of both lower bound and upper bound cases.

Below shows the MATLAB designed diagrams of BBBC & GWO and their respective output waveforms and performance table values and comparison values.GWO values are found through designing of MATLAB code in 2016a.

V. RESULTS

BLOCK DIAGRAM OF FOPID-BBBC & GWO:

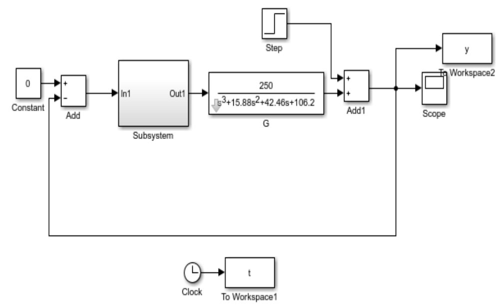


Figure .4. Block diagram of FOPID-BBBC.

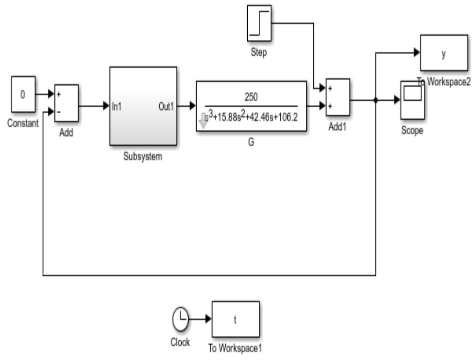


Figure .5. block diagram of FOPID-GWO

COMBINATION DIAGRAM OF FOPID-BBBC & GWO NOMIMAL CASE:

below shows the nominal case diagram of GWO & BBBC.

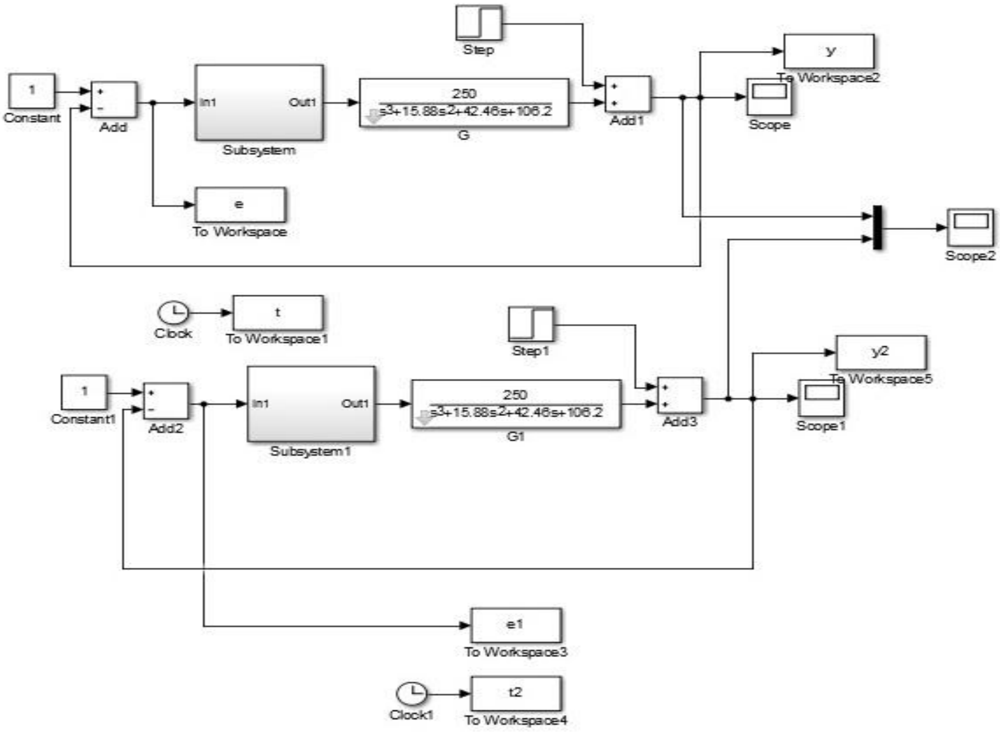
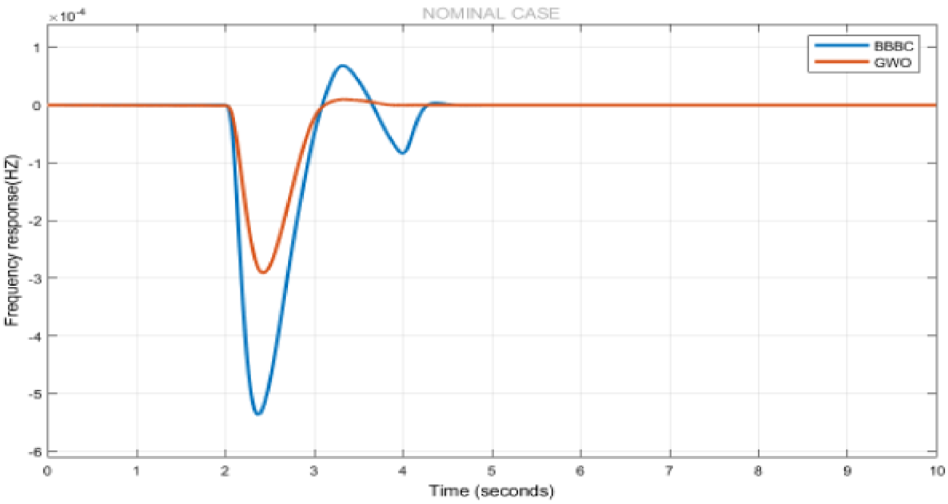


Figure 6. combination diagram of FOPID-BBBC & GWO.

OUTPUT WAVE FORM COMBINATION OF BBBC & GWO NOMINAL CASE:



Figuer.7. output wave form response of both BBBC & GWO nominal case.

Above waveforms tells the frequency response with respect to the time of the BBBC & GWO optimization techniques. we observed that the settling time of grey wolf optimization is gives better settling value when compared to the BBBC optimization technique.The red line tells the GWO optimization line & sky blue line tells the BBBC optimization technique.

Table 2: Nominal Case Parameter Values Of BBBC: 1.Bbbc Values:

Table 2 is Performed parameter values of occurred for FOPID via BBBC. & e= ×10 taken in below tables.

Symbols	Minimum	Maximum	Mean value	Variable	STD
K_p	11.99312141	15.46939153	13.03170498	$2.154283450e^{-01}$	$3.39747473e^{-01}$
k_I	34.12074203	56.50364387	38.51758498	$4.607766461e^{-00}$	$2.14657086e^{-00}$
k_D	3.35099794	5.13659361	7.642443733	$4.30024957e^{-04}$	$3.81665890e^{-02}$
Λ	0.68820845	0.71083348	0.69851186	$1.86954940e^{-05}$	$4.32382863e^{-03}$
μ	1.32108221	1.34214655	1.33199057	$2.005002773e^{-05}$	$4.47772569e^{-03}$
t_s	4.04151923	4.25671471	4.16944216	$1.99846977e^{-03}$	$4.47042478e^{-02}$
t_r	$3.22668747e^{-04}$	$3.63052749e^{-04}$	$3.44575487e^{-04}$	$6.31616028e^{-11}$	$7.94742743e^{-06}$
Under shoot	$9.03392500e^{-04}$	$9.54825200e^{-04}$	$9.29050369e^{-04}$	$9.29050369e^{-10}$	$1.05101837e^{-05}$
Over shoot	$1.86539200e^{-05}$	$3.37651200e^{-05}$	$2.60463279e^{-05}$	$8.49926057e^{-12}$	$2.915349133e^{-06}$
ISE	$1.58440974e^{-07}$	$1.60148063e^{-07}$	$1.59390015e^{-07}$	$1.57634433e^{-19}$	$3.97032030e^{-10}$
IAE	$5.99981429e^{-04}$	$6.21553431e^{-04}$	$6.10587461e^{-04}$	$2.13431837e^{-11}$	$4.61986836e^{-06}$
IATE	$2.35540422e^{-03}$	$2.55441129e^{-03}$	$2.47971083e^{-03}$	$1.03848684e^{-09}$	$3.22255619e^{-05}$

Best solution is $K_p = 12.95296112$, $K_i = 39.89256956$, $K_d = 4.66322410$, λ=0.76835679, & μ=0.91400910.

Table 3. Petrubasion & Nominal Case Values Lower & Upper Bound Of Bbbc :

BBBC CASE:

Design method:	Perturbationcase :ISE	IAE	IATE	Nominal case: ISE	IAE	IATE
LOWERBOUND	$2.7105e^{-07}$	$6.8817e^{-04}$	$2.6528e^{-03}$	$2.7105e^{-07}$	$6.8817e^{-04}$	$2.6528e^{-03}$
UPPER BOUND	$2.7111e^{-07}$	$6.8813e^{-04}$	$2.6529e^{-03}$	$1.5842e^{-07}$	$6.1078e^{-04}$	$2.4937e^{-03}$

Table 3 Below shows the BBBC petrubasion case.

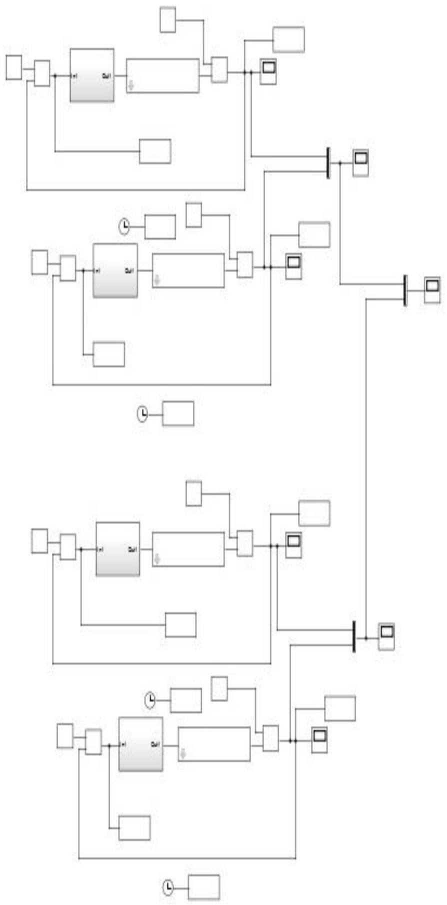
Table .4: Obtained Nominal Case Parameter Values Of Fopid Via Gwo: Table 4.shows the parameters occurred for FOPID via GWO in nominal case.

Best solution is $K_p = 5.49772066$, $K_i = 3.13332847$, $K_d = 1.77083909$, λ=0.47069739, & μ=0.29249624.

Table 5.Gwo Case (Petrubasion & Nominal):

Design method:	Perturbation case: ISE	IAE	IATE	Nominal case: ISE	IAE	IATE
LOWERBOUND	$1.73646733e^{+03}$	$4.69624526e^{+01}$	$2.10555524e^{+01}$	$1.7105e^{-07}$	$5.8817e^{-04}$	$1.6528e^{-03}$
UPPER BOUND	$1.7663799e^{+01}$	$5.04870979e^{+01}$	$3.15544362e^{+01}$	$1.8842e^{-07}$	$5.1078e^{-04}$	$2.3937e^{-04}$

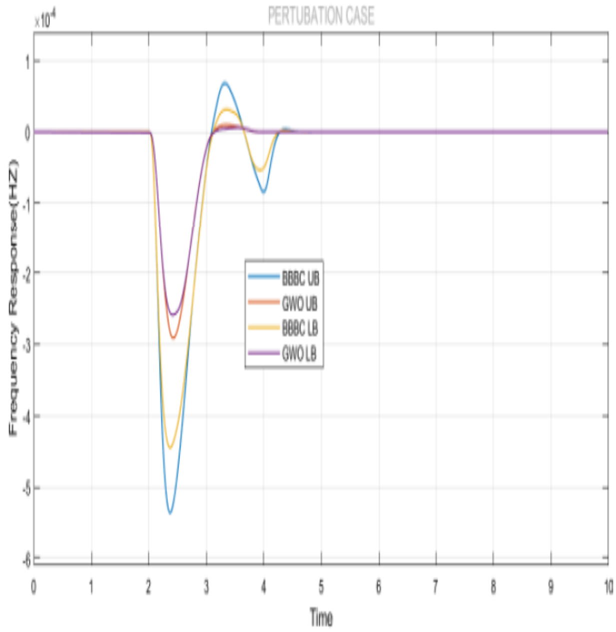
PETRUBASION CASE DIAGRAM OF COMBINATION OF UPPER BOUND AND LOWER BOUND CASESS OF GWO & BBBC:



Figuer.8.petrubasion combination diagram.

The respective frequency response outputs of BBBC, GWO lower& upper bound combination are show below.

PETRUBASION CASE OUT PUT WAVE FORMS:



Figuer.9.petrubasion case combination output wave forms.

VI. CONCLUSION

Finally in this paper work we done the development of optimized FOPID controller for a single area system with non-reheated turbine to the electrical power system via GWO optimized algorithm through IMC scheme.In this paper we observed that the proposed method is have extremely fast disturbance rejection capability in load frequency disturbance problem when compared to the BBBC optimization technique. GWO optimization technique gives better parameter values when compared to the BBBC optimization technique in the lower bound and upper bound cases. In this paper proposed executed method is discussed single area system but also in future applicable to more than two areas with non-reheated turbine . This process may be applicable to the power system with re-heated turbine and hydrological turbines.

REFERENCES

1 Shivam Jain, Yogesh .V (2018), Design of fractional PID for Load frequency control through the Internal model control and Big bang Big crunch optimization.

2 Cavin R.K., Budge, M.C., and Rasmussen, P. in the year (1971). The optimal linear systems approachment to load-frequency control. IEEE.

3 munro c, esscobedo r, spector l, coppinger r. Grey Wolf-pack (Cannis lupus) Hunting strategies Emerging from simple rules in computational simulations process(2011).
4 Pandey.S.K.. ,Mehanty S.R., and Kishor N.(2013). The literature survey on load -frequency control for conventional and distributed generation power systems.
5 S. Mirjalili, s. M. Mirjalili, and a. Lewis, "grey wolf optimizer," advances in engineering software, (2014).
6 Biradar, S., Hote, Y.V., and Saxena, S. (2016).
7 Reduction ordered modeling of linear time in-variant systems using BB-BC optimization and & time moment matching method. Applicable Mathematically Modeling, 40 (15), 7225 – 7244.

AUTHORS PROFILE

Bhavandla.Bhanupradeep, student ,currently pursuing M.tech in Power Systems (EEE) from GRIET, Hyderabad ,India . B.tech in EEE from Sree Kavitha Engineering college, karepally, telangana ,India. Email: bhanujeevan@gmail.com.

Dr Dola Gobinda Padhan is a Professor of Electrical and Electronics Engineering Department, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad. He did M.Tech. From NIT, Bhopal and Ph.D. from IIT, Guwahati in the year 2002 and 2012 respectively. He also has to his credit a number of papers published in reputed journals and presented in major conferences. His areas of research include time delay systems, systems identification, tuning of controllers and control theory applications.