ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

INVESTIGATION OF CASCADED 2DOF-PID CONTROLLER WITH IMPROVED INVASIVE WEED (IIW) TECHNIQUE

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ABSTRACT

A vast increment in power utilization aims towards the increment in power generation, leading to complex advance in the control. The control approach for frequency change with load is mainly exhibited in four main groups. Initially, the Type of controller-Classical control approach involved the design of different controllers in reducing divergence in frequency due to load perturbations and Tie-line power flow due to power exchange between areas. In this work a novel cascaded 2-Degree of freedom PID controller is proposed, and comparative analysis is done with 2-Degree of freedom PID controller and PID is applied in a secondary regulatory framework for multi-area interconnected power systems, and investigations are carried out during random load disturbances, plant generation participation changes, and parameter variations. Finally, Soft computing approaches- optimizable techniques for tuning the controller parameters. Due to utilization primary controller schemes will makes the response to a very large time. Hence to obtain fast response a fast controller scheme is required which has been proposed in this work. In view of various metaheuristic techniques available can be utilized for gain optimization parameters and better solution.

Keywords: *Cascaded two-degree freedom controller, Improved Invasive weed technique.*

1. INTRODUCTION

As energy generation using conventional sources (thermal, hydro) is variable, there is a need for secondary action of control to obtain stable system operation. The imbalance in power between load and source causes deviation of frequency, increases the system complexity, and reduces the healthy condition of the overall system. Based on heuristic algorithms for tuning the parameters of secondary controllers and intelligent controllers' help, various schemes of mechanism for secondary control can be found in the literature.

To one side of classical controllers, several structures such as modification of primary controller, parallel combination, cascading of one with other controllers are proposed in this work. In this work, in the initial stage, the particle swarm optimization algorithm (PSO) is used as a primary technique for gain parameter tuning for controllers of LFC. Another approach named differential evolution (DE) replaces PSO [1]. Cascading of different controllers is done in the literature using bat algorithm (BAT) proportional derivative [2], and proportional integral and derivative (P-D/P-I-D) were first proposed in the literature. A controller is proposed with the combination of regular P-I-D with a freedom controller of degree two (2-DOF-PID). This combination is connected in parallel with each other as a centralized structure [3]. A few plants interconnection in parallel controller operation is challenging to control. For adjusting the gain parameters of the controller proposed, the IWO algorithm is used. It provides better results with controller limiting extreme points that provide more suitable for search phenomenon. A comparative analysis with various methods for optimization of the proposed controller is done, and results show that the proposed algorithm provides better results than other algorithms.

2. STRUCTURE ANALYZED

For simplicity, a general representation of a single area block diagram is presented in figure1. Each area consists of one non-reheat thermal plant and another hydro plant without considering governor dead bands [4]. These are the control participation factors of each plant in an area,

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

respectively. Each plant will have primary and secondary regulation loops. are considered the primary regulation loop factors, and with multi-input proposed 2-DOF combined with conventional PID controller is equipped with the secondary control loop [5]. Depending upon the values of participation factors of the particular machine, the centralized proposed controller offers concurrent signals to each plant for the process of load frequency control problem. The thermal plant considers power generation with load variation in the second case [6]. Hence, the participating factor in the frequency control is kept as one, and power generation with a hydro plant is regarded as zero. The participating factor in the frequency control is taken as zero.

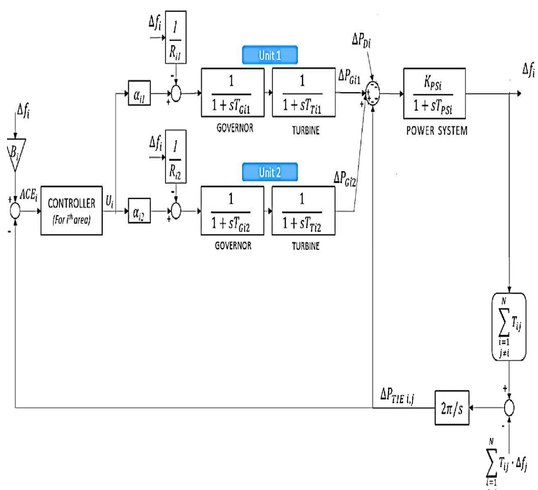

Figure 1: Schematic block diagram illustration with two Area system (i=1,2)

2.1. Cascaded 2D-FO-PID Controller

With intensive literature survey results consideration with different techniques in this study, two controllers are considered which seems to be better chosen for designing of proposed controller scheme. From the survey, two controllers, i.e., traditional P-I-D controller and 2-DOF P-I-D controller, are considered in this work. The 2-DOF P-I-D controller is advanced to the conventional P-I-D controller in performance in different conditions load perturbations. Hence, the 2-DOF P-I-D controller is better opted with a control system's performance specifications that benefit from conventional P-I-D [7].

An illustration of the proposed scheme of the controller is illustrated in figure 2. The illustration of block diagram with representation in figure 2. the top section of the diagram is 2-DOF P-I-D, and the bottom section represents the traditional P-I-D controller [7]. The output signal of 2-DOF P-I-D is termed as and the output of the traditional P-I-D controller is stated as the required output of the proposed scheme is the difference between the two signals $U_1(s) - U_2(s)$ is the controller reference signal which here is the difference of the information regarding ACE, is the output signal, which here is the deviation of frequency in a particular area, and is defined as a filter coefficient [8].

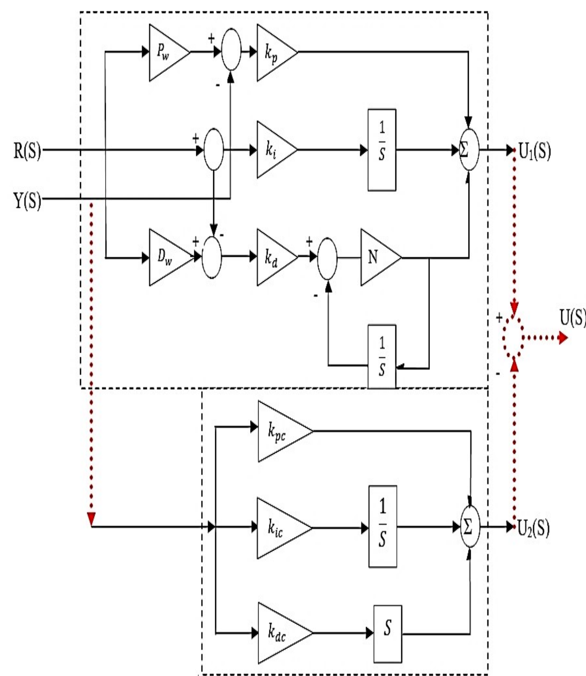

Figure 2: Schematic block diagram illustration of a Proposed controller

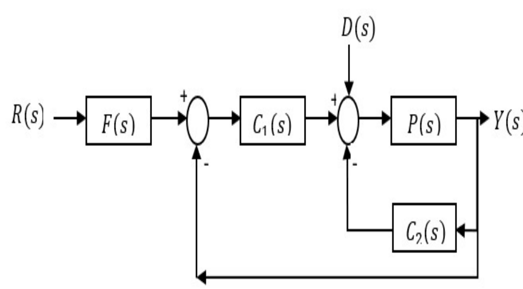

Figure 3: Schematic representation of control system connection structure

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

To make the analysis more accessible, the structure proposed controller connection in the control system is illustrated in Figure 3. with $P(s)$ is the plant representation, $D(s)$ Is the plant's disturbance transfer function. The additional transfer function blocks in the illustration enhance the system's stability and fast response as the structure possesses regular P-I-D properties. In the absence of transfer function block $C_2(s)$ The structure of the control system is close to the traditional 2-DOF P-I-D. The transfer function $C_1(s)$ is to reduce noise in the system. As noise signals are generally reduced using derivative terms hence the transfer function of $C_1(s)$ is nearer to the derivative term. The first-order filter is $C_1(s)$ cascaded Term for tuning its poles, so the effect of chattering is eliminated. Otherwise, it will produce high noise frequency with attenuation.
The control signal of the proposed scheme under dynamic operating conditions with its response nearer to the preferred value is defined from the equation below:

$$U(s) = F(s).C_1(s).R(s) - (C_1(s) + C_2(s)).Y(s) \quad (1)$$

As the proposed controller is a cascade of 2-DOF PI-D and P-I-D controllers [9], the system is more stable with the extra term in equation (1), which provides a quick and stable. response compared with conventional 2-DOF P-I-D and PI-D controller [11].

$$F(s) = \frac{(P_w k_p + D_w k_d)S^2 + (P_w k_p N + k_i)S + k_i N}{(k_p + k_d N)S^2 + (k_p N + k_i)S + k_i N} \quad (2)$$

$$C_1(s) = \frac{(k_p + k_d N)S^2 + (k_p N + k_i)S + k_i N}{S(S+N)} \quad (3)$$

$$C_2(s) = \frac{k_{dc}S^2 + k_{pc}S + k_{ic}}{S} \quad (4)$$

3. PARAMETER TUNING USING IMPROVED INVASIVE WEED TECHNIQUE

The most discomforting and robust plants in agriculture are generally known as weeds. The incident in which a class of individuals (weeds) migrate to a new environment and contend with the local population is known as a biological invasion [10]. Weeds are generally characterized by invasion, robustness, and adaptiveness.

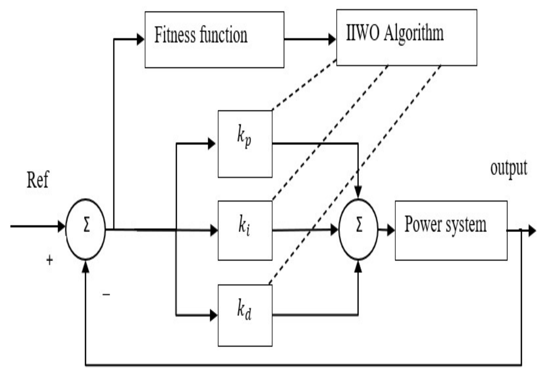

Figure 4: Schematic Illustration of proposed tuning technique

Weed is also termed a phenomenon that ideally searches for better environmental conditions with causing changes in its resistivity and adapts to the changes with the environment [11]. The intense growth of herbs, generally known as weeds, causes severe problems to the existing crops due to their aggressive growth. Due to changes induced in the environment, they adopt it with their changing resistance[12].

4. SIMULATION AND RESULTS DISCUSSION FOR DIVERSE CASE STUDIES

The strategy of the proposed controller is studied by considering three different case studies [13]. The chronic cases simulate the first and second studies present in the earlier schemes. The third one is the new scenario contribution of the system with the respected fitness function, which shows the usefulness of the proposed controller to recognize broadly .

Case Study-1: In this study, a 10% load perturbation is deemed in each area and compared the effect of the proposed controller with a regular P-I-D controller and 2 DOF P-I-D controller on the proposed test system. A zero delay in the control action of the generators is considered for both the plants in each area to diminish the change in load. Optimal gain parameters of the controllers (Proposed, P-I-D & 2 DOF P-I-D) are obtained with tuning with the IWO algorithm and present in Table 1.1.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 1.1: IIW, Optimal tuned Parameters of Controller

Gain parameters	Area:1			Area:2		
	PID	2-DOF PID	Proposed	PID	2-DOF PID	Pro
k_p	- 1.998	0.998	0.9994	0.7853	0.776	0.882
k_i	- 1.993	- 0.997	0.5881	- 0.0589	- 0.011	0.064
k_d	- 1.999	0.995	0.4741	0.2161	0.547	0.321
P_w	-	- 2.0	- 1.997	-	0.419	- 1.952
D_w	-	- 0.657	0.327	-	0.680	- 1.558
N	-	90.503	98.43	-	93.063	34.25
k_{pc}	-	-	- 1.999	-	-	- 0.9273
k_{ic}	-	-	- 1.999	-	-	0.0872
k_{dc}	-	-	- 1.751	-	-	- 0.069

Discussions:

The proposed controller provides better results than P-I-D and 2 DOF P-I-D controllers regarding frequency and tie-line power disturbances and oscillations, respectively, because of (combined P-I-D structure of controller). The dynamic parameters change such as settling, under, and errors in the steady state are less with a proposed controller. A detailed comparative description of the performance analysis with a different controller is tabulated in Table 1.2.

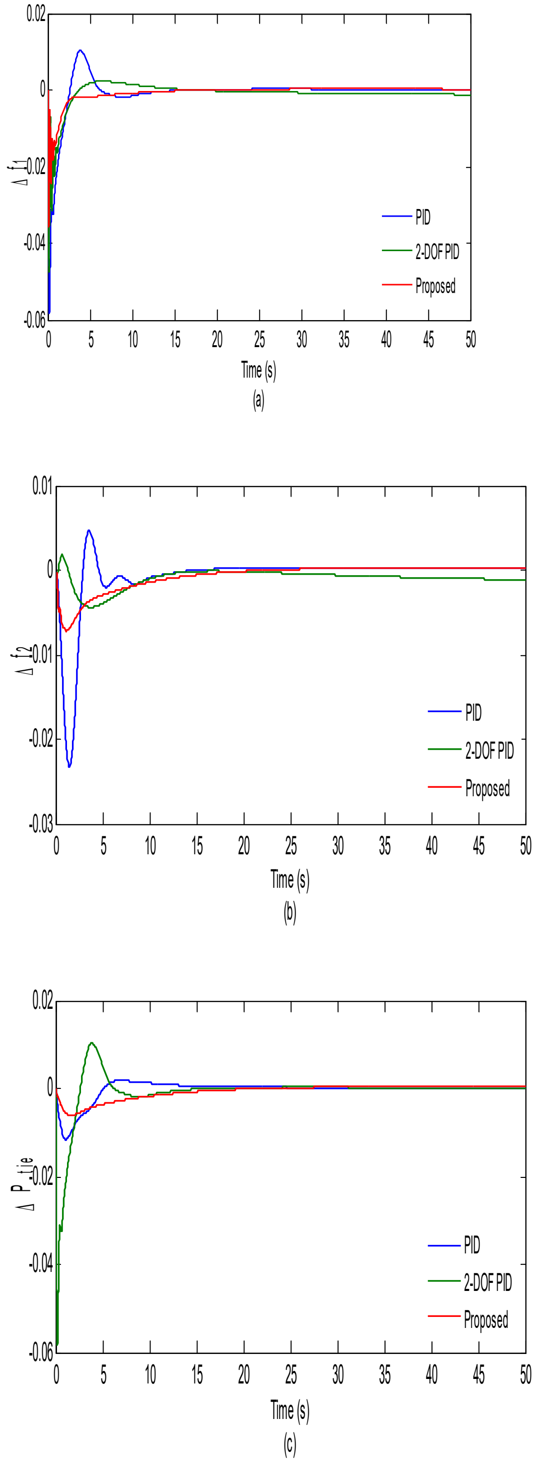

Figure 5: Case study-1, frequency & tie-line responses a. Δf_1, b. Δf_2,c. ΔP_{12}

Journal of Theoretical and Applied Information Technology
29th February 2024. Vol.102. No 4

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 1.2: Cmparison with different controller performance

parameters	Δf_1			Δf_2		
	PID	2DOF PID	Proposed	PID	2-DOF PID	Pro
Peak value (p.u)	- 0.058	-0.047	-0.035	-0.023	18.0 x10^{-2}	-7.2 x10^{-3}
Settling (S)	16.01	14.02	10.03	20.02	16.01	16.01
Error (p.u)	-16x10^{-2}	15 x10^{-2}	8 x10^{-2}	24 x10^{-3}	-7.0 x10^{-5}	2.2 x10^{-4}

Case study-2: To examine the frequency controller effects with frequency regulation of the system, a 10% load variation is considered at zero seconds in area-1. Optimal gain controller parameters are done with the IWO algorithm and tabulated in Table 1.3 for all three controllers.

5. DISCUSSIONS:

The importance of the proposed controller can be seen reasonably (better) in Case study-2 compared with case study-1. In participation factor theories, the conventional P-I-D and 2-DOF P-I-D controllers botched to provide a fast, highly stable output. The proposed controller proved to be the best in this theory. The P-I-D controller's integral control parameter within the fixed limits can't obtain zero steady-state error and terms to oscillate. In the 2-DOF P-I-D controller with the proposed system, the steady-state error to zero value can be achieved, but it takes a lot to happen, which means the controller is slow in responding.

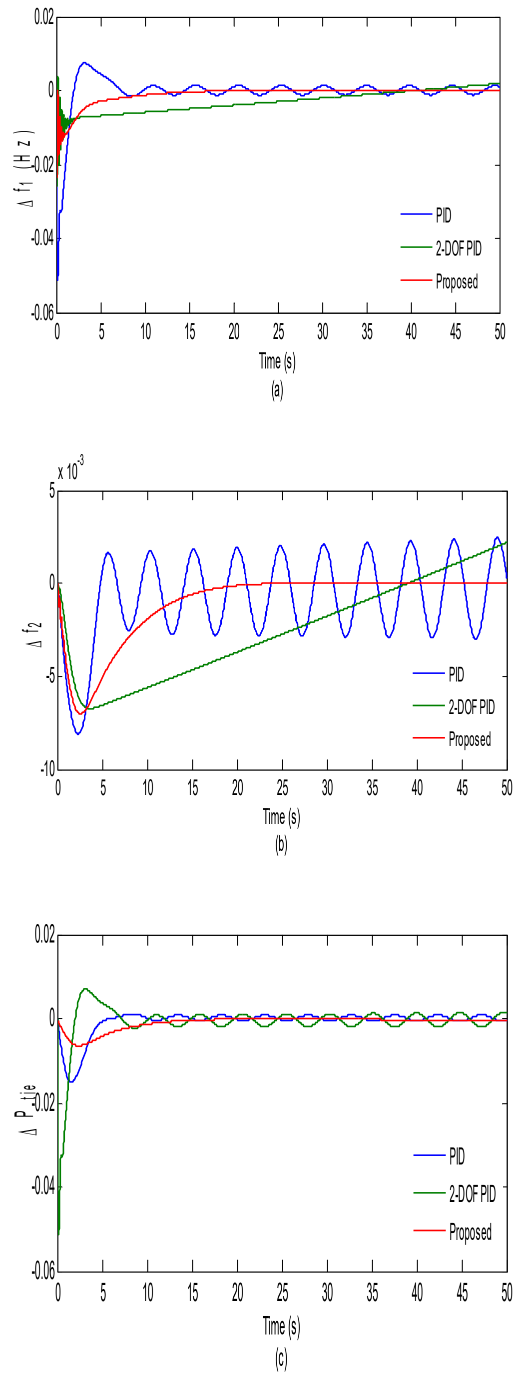

Figure 6: Case study-2, frequency & tie-line responses a. Δf_1, b. Δf_2,c. ΔP_{12}

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Table 1.3: IIW, Optimal tuned Parameters of Controller for case study 2

Gain parameters	Area:1 Centralized controller			Area:2 Centralized controller		
	PID	2 DOF PID	Pro	PID	2 DOF PID	Pro
k_p	-1.99	1.99	1	0.94	1.46	0.02
k_i	-1.9	0.00	0.278	-0.0	0.09	0.019
k_d	-1.99	1.42	0.99	0.379	1.51	0.991
P_w	-	-1.99	-2.0	-	-0.89	-0.92
D_w	-	-1.8	-1.57	-	0.14	-1.99
N	-	99.4	87.02	-	40.2	94.63
k_{pc}	-	-	0.98	-	-	0.256
k_{ic}	-	-	1.99	-	-	-0.023
k_{dc}	-	-	1.63	-	-	1.437

Table 1.4: Comparison with different controller performance-2 ($\Delta f_1, \Delta f_2$)

Dynamic parameters	Δf_1			Δf_2		
	PID	2 DOF PID	Pro	PID	2 DOF PID	Pro
Change in Peak value (p.u)	-0.05	-0.02	-0.02	-8.1	-6.8	-7
Time for Settling (S)	----	0.40×10^{-2}	0.20×10^{-2}	----	0.40×10^{-2}	0.20×10^{-2}
Steady state error (p.u)	1.32	0.84	0.0	2.48	1.0	0.0

Table 1.5: Comparison with different controller performance ($\Delta P_{12} - 1\&2$)

Dynamic parameters	ΔP_{12} (case study – 1)			ΔP_{12} (case study – 2)		
	PID	2 DOF PID	Pro	PID	2 DOF PID	Pro
Peak value (p.u)	-0.01	-0.05	-0.006	-0.01	-0.015	-0.065
Settling (S)	20.0	18.0	18.0	----	----	15.0
state error (p.u)	0.13×10^{-7}	0.22×10^{-7}	0.39×10^{-7}	1to2 $\times 10^{-3}$	1to 2 $\times 10^{-3}$	25 $\times 10^{-3}$

Case study 3:

In this study, random load changes are considered for the proposed scheme performance evaluation. As from previous studies, optimal parameter tuning for Proposed, P-I-D & 2 DOF P-I-D controllers is done with the IWO algorithm. The changes in load of 1% initiated at 0 seconds, 4% at 20 seconds, and 6% at 40 seconds to w.r.t zero references, respectively.

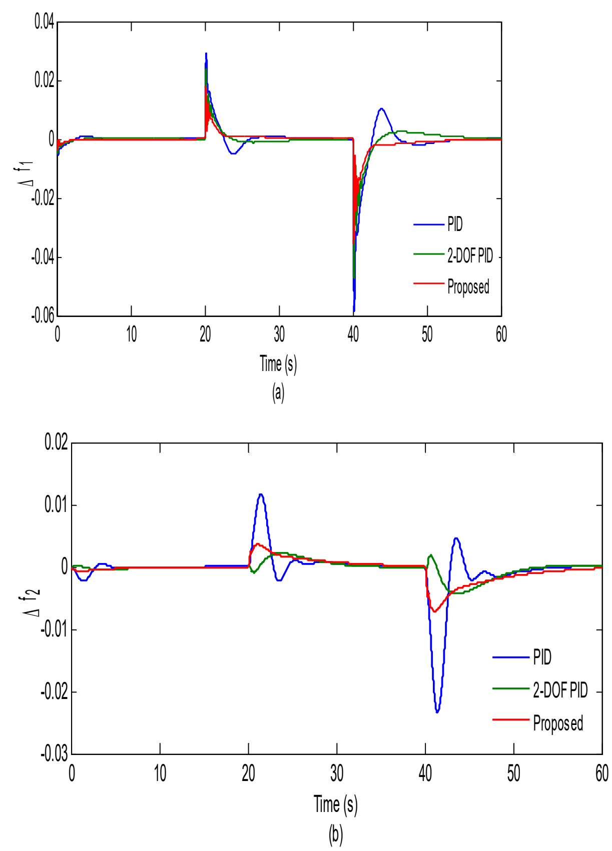

Figure 7: Case study-3, frequency responses a. Δf_1, b. Δf_2,

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Table 1.5: Comparison with different controller performance-3 ($\Delta f_1, \Delta f_2$)

Dynamic parameters	Δf_1			Δf_2		
	PID	2 DOF PID	Pro	PID	2 DOF PID	Pro
Change in Peak value (p.u)	-0.05	-0.02	-0.02	-8.1	-6.8	-7
Time for Settling (S)	----	0.40 x10^{-2}	0.20 x10^{-2}	----	0.40 x10^{-2}	0.20 x10^{-2}
Steady state error (p.u)	1.32	0.84	0.0	2.48	1.0	0.0

5. COMPARISION OF DIVERSE OPTIMIZATIONS

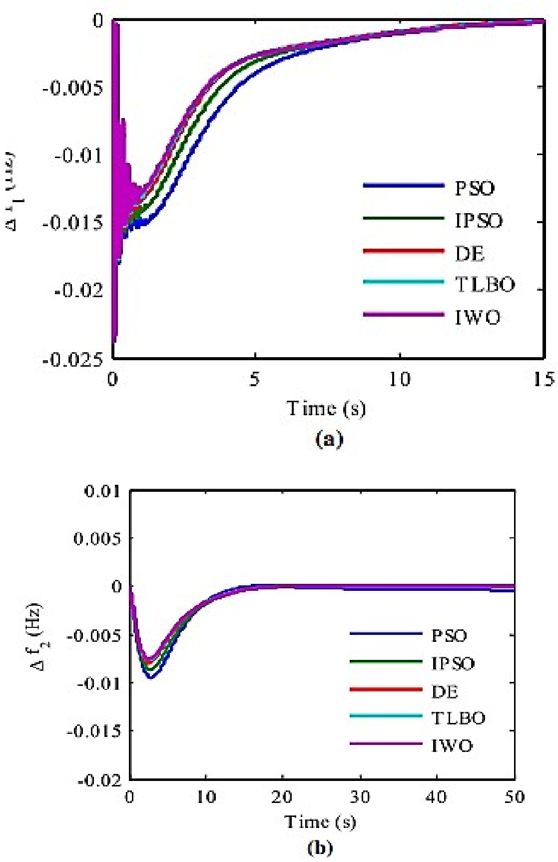

Figure 8: Comparison of Frequency responses with Diverse optimization techniques.

Comparative analyses with different Diverse optimization techniques are studied. The proposed algorithm IIW with the proposed controller is compared with PSO, IPSO, DE, TLBO, IWO.

This work simulates the various controllers with less response time compared to available controllers in literature review. Future utilization of various optimization techniques makes the system compatible and provides better results. The drawback of the present system is response time is more and can be reduced by considering a suitable optimization technique.

6. CONCLUSIONS

Improved Invasive Weed was used with different case studies to obtain optimal gain values of proposed and conventional schemes instead of the trial-and-error method. For the control of generating output, a standard controller, which is proposed in this work, is sufficient for obtaining desired responses. The new proposed controller, which is an integration of cascaded structured 2DOF P-I-D presented in this work, shows its superiority in minimizing frequency deviations that are caused when a load change occurs in the system. The proposed controller gives a better control signal based on plants operation with various participation factors imposed on it. The proposed controller is the best choice for maintaining constant frequency, which makes the system stable, with the complex case studies considered in this work.

7. LIMITATIONS & FUTURE SCOPE:

This work is limited to practical applications due to time responses of various controllers and can be further related nearly to practical system by using opal rt software. Future with the utilization of various available controller schemes available in present literature can make the study of system with better responses.

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