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Controlling load frequency of six area power plant using optimization methods in Iraq electric sector

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Abstract
Maintaining a constant frequency output is essential for the stability and dependability of power transfer between power plant systems; any imbalances could have catastrophic consequences for the power system as well as the consumer where A control solution that makes use of six proportional integral derivative (PID) controllers and two sophisticated optimization techniques Improved Chaotic Electromagnetic Field Optimization (ICEFO) and Electric Charged Particles Optimization (ECPO) is presented in order to guarantee the avoidance of such circumstances and Additionally, this approach is used to address load frequency management problems in Iraq's six interconnected electricity systems as well as Two optimization techniques for PID controllers used for load frequency control are presented in the study while The outcomes show good performance, especially when the ECPO algorithm is used in combination with the PID controller. When this combination is used instead of the PID controller and the ICEFO algorithm, the system stabilizes more quickly also In the majority of areas, the PID-ECPO approach consistently produces low settling time values and applicable overshoot/undershoot values where in our study The average improvement in settling time was about 40.7% (a reduction of 15.9 seconds), the average improvement in overshoot was 97% (complete elimination), and the average improvement in undershoot was 98% (complete elimination).

Keywords: Load frequency control, improved chaotic electromagnetic field optimization, electric charged particles optimization, proportional-integral, derivative

1. Introduction

This engineering study develops one of the most important control systems involved in electricity generation: turbine speed regulation where This system maintains the stability of the generating unit and then appropriately selects an automatic speed regulation system for the Coline mini hydroelectric plant, located in Marcapata [1, 2] This is intended to provide a definitive solution to improve the quality and efficiency of electrical energy production and the safety of the entire generating set by replacing the current manual turbine regulation system with an automatic one additionally To achieve this, the best speed regulation system and equipment must be selected from the different available technological options, taking into account their technical parameters and functional aspects, according to the type of turbine and generation capacity, without neglecting the economic aspect, given that this is a mini hydroelectric plant so Therefore, it is not necessary to live with the problem, but rather to find an optimal and viable solution that can be subsequently implemented [2, 3].

The lack or inadequacy of electricity in the country, especially in remote and hard-to-reach areas, whose electrification factor remains low compared to other cities as well as This, coupled with the distance of the interconnected system's transmission lines and the rugged geography of the area, means that smaller population centers such as Kulin and others in the community of Boyka lack access to electricity. To address these energy needs in Boyka, an assessment was conducted in 2005 for the construction of a small hydroelectric power station. It found favorable topographical and hydraulic conditions to make an isolated small-scale power generation system viable [4, 5, 6] The project considered a generating capacity of 140 kilowatts, sufficient to supply power to the entire community, which lacks this vital service, hindering its social and economic development while electrical service in this rural community is deficient due to constant fluctuations in voltage and frequency, primarily caused by the lack of a system to regulate the speed of the station's generator, which maintains it at its nominal value. This situation limits power quality and prevents efficient service. This leads to deterioration, premature aging, or failure of users' electrical Nevertheless, Authors in [10, 11, 12], Implemented Magneto Equipment [7, 8, 9]. Tactic Bacteria Optimization (MBO) to optimize Integrated Double-Derivative (IDD) controllers with FLC in hybrid power systems. While the system was found to outperform classical controllers, no comparisons to other optimization techniques were done. To fine-tune controller settings, the authors' in [13, 14, 15], proposed approach for LFC of a multi-area power system employs an Integral Derivative-Tilted (ID-T) controller and the Archimedes Optimization Algorithm (AOA). The suggested controller outperforms previous optimization methods and increases frequency stability, however the study did not compare its performance and complexity to other state-of-the-art control systems. On the other hand in [16], a Harris Hawks Optimizer (HHO) technique was proposed for LFC in multi-connected systems with renewable energy sources. The results reveal that the proposed solution was more reliable and superior to existing optimizers and traditional controllers for two interconnected power systems. However, the study only covers two interconnected power systems, restricting the proposed methodology's applicability to other power systems.

Based on Electric Charged Particles Optimization algorithm (ECPO) [17], a modified ECPO was proposed that called MECPO, which improved the search capability through three interaction strategies also in The study evaluated the algorithm's performance on CEC'17 and applied it to estimate photovoltaic model parameters where the study had not guaranteed optimal solutions for all problems and required careful parameter tuning [18] 3D wind farm layout optimization approach was recommended using an enhanced ECPO algorithm, which was tested on four case studies then Admittedly, the operation was based on certain assumptions such as uniform wind distribution and complete lack of obstacles that might or might not represent the real conditions of most wind farms. It has been observed that traditional methods of LFC have proven effective in managing the balance between power generation and load demand in power systems so However, these methods showed limitations and fail to guarantee the best system balance outcome and For that reason, this work is proposed the utilization of PID controller joined with ICEFO and ECPO algorithms for enhanced LFC in a six-area power plant system in Iraq. ICEFO and ECPO are powerful and dependable optimization techniques that can be utilized to boost efficiency and stability in power systems [19, 20].

This paper seeks to address the challenge of LFC of six power plants in Iraq. A PID controller along with two advanced optimization algorithms which are ICEFO and ECPO algorithms that used in Section 2. Section 3 delves deeper into the proposed algorithms and their integration with the PID controller and equations utilized. While Section 4 presents the results and discussion that includes comparison tables to show the effectiveness of each optimization method

2. Methodology

2.1 PID Controller

This methodology focuses on two optimization algorithms used to control load frequency in six power plants using a PID controller. The first, ICEFO, uses chaos mapping to increase exploration capacity, while the second, ECPO, mirrors particle behavior under electric fields to resolve optimization problems. The analysis of the PID controller's implementation, system transfer functions, and parameters is provided. The goal is to improve exploration of the chaotic map with the ICEFO algorithm and imitating particle behavior with ECPO to uncover new ways of controlling load frequency in the six power plants. The implementation of PID controllers in load frequency control has gained attention, but their performance depends on precise parameter tuning.

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

Where $G_g(s)$ is governor transfer function, T_g is the governor time constant.

$$G_r(s) = \frac{1}{T_r s+1} \quad (2)$$

Where $G_r(s)$ is non-reheated-turbine transfer function, T_r is the non-heated-turbine time constant.

$$G_w(s) = \frac{1-T_w s}{1+0.5T_w s} \quad (3)$$

Where $G_w(s)$ is hydraulic turbine transfer function, T_w is the hydraulic turbine time constant.

$$G_p(s) = \frac{1}{2Hs+D} \quad (4)$$

Where $G_p(s)$ is load turbine transfer function, H is the generator inertia constant, D is load varies percent divided by the change of frequency percent.

3. Results and analysis

The power system imbalances brought on by the correlation between the load frequencies of six power plants are addressed in this paper. It suggests using two optimization techniques to enhance controller performance and constructing six PID controllers to lessen power and frequency disparities. Additionally, the study offers a thorough examination of suggested control schemes and how they affect the behavior of the system.

Table 1: The parameters of Iraqi Meddle Area.

Area	Name	Turbine Type	Code	D	H	T_g	T_t	R	T_{ws}
1	Al-Mansorya	Gas	MNSG	0.8	6	0.1	0.6	0.04	
2	Al-Quds	Gas	QDSG	0.8	6	0.1	0.6	0.04	
3	Al-Sadar	Gas	SDRG400	0.8	6	0.1	0.6	0.04	
4	Basmaya	Gas	BSMG	0.8	6	0.1	0.6	0.04	
5	Wasit	Hydro	KUTP	0.9	5	0.2	0.7	0.05	
6	Hadytha	Hydro	HDTH	0.8	6	0.2	0.5	0.05	2.0

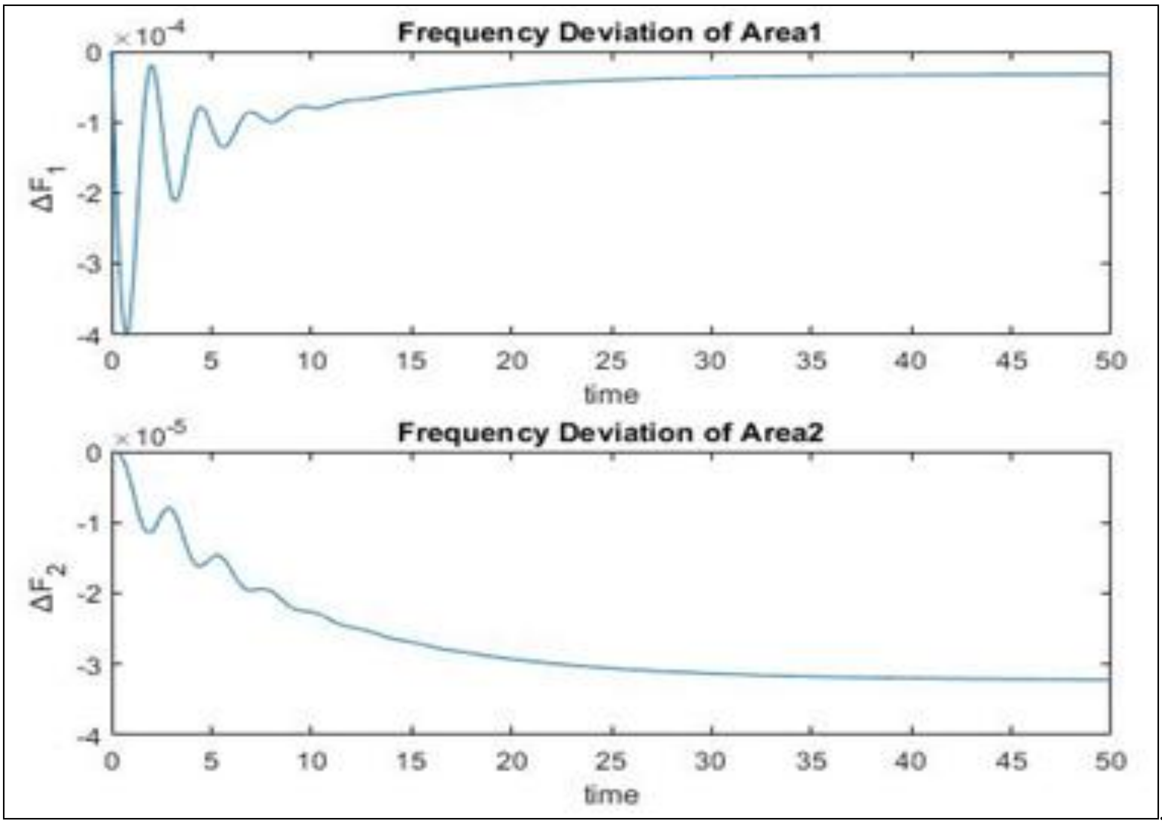

Fig 1: Frequency deviation over time for area 1 and 2.

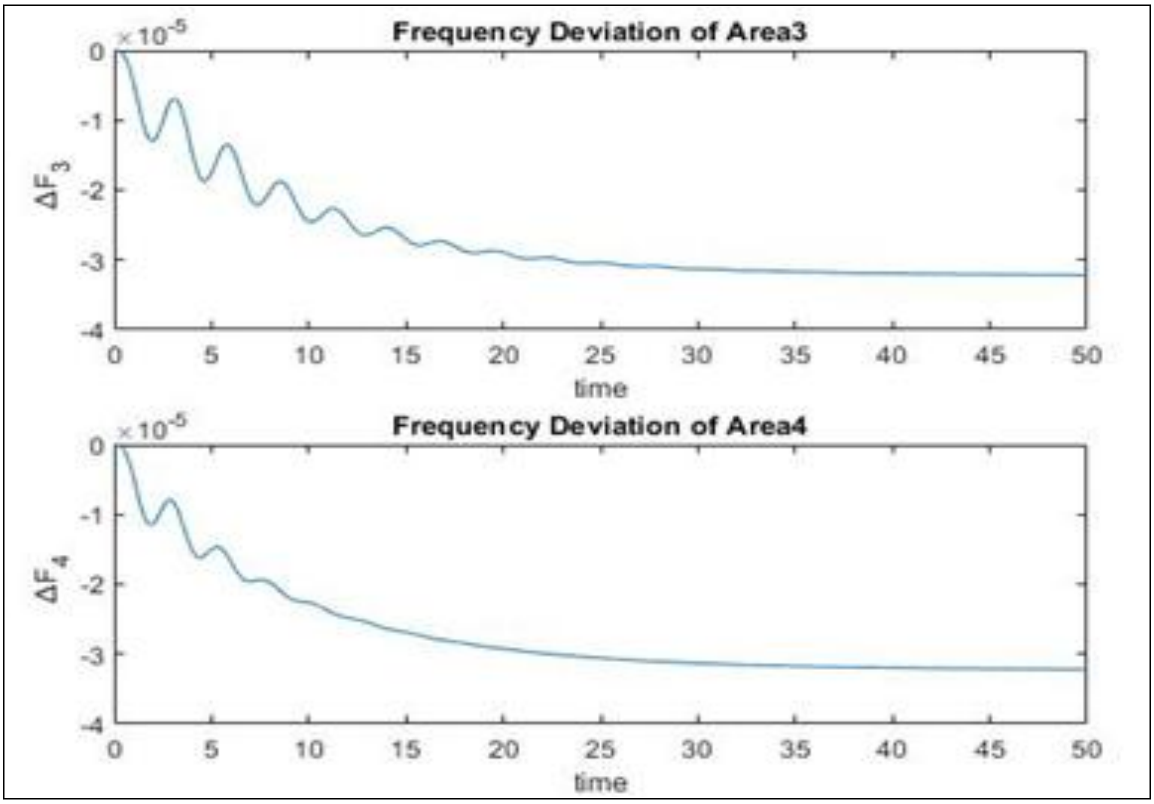

Fig 2: Frequency deviation over time for area 3 and 4.

Frequency deviation in the Wait and Hadytha sectors is depicted in Figure 3, where Wait stabilizes gradually after 15 seconds and Hadytha stabilizes more quickly in just 10 seconds.

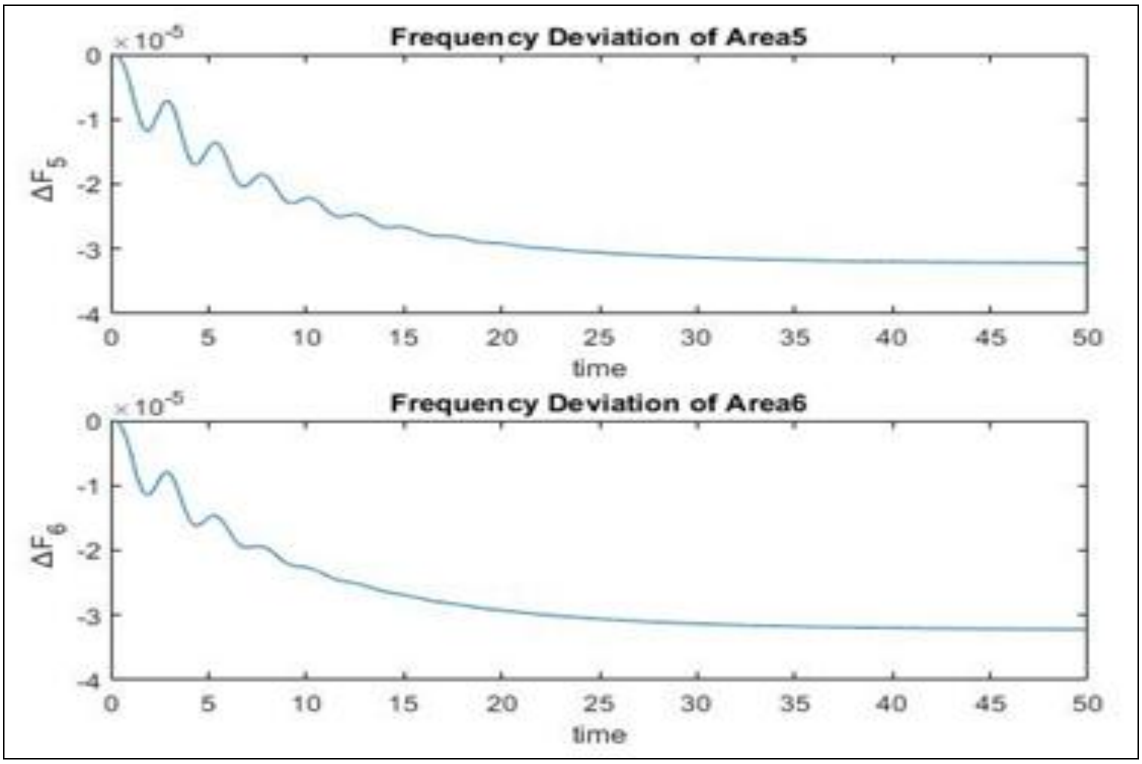

Fig 3: Frequency deviation over time for area 5 and 6.

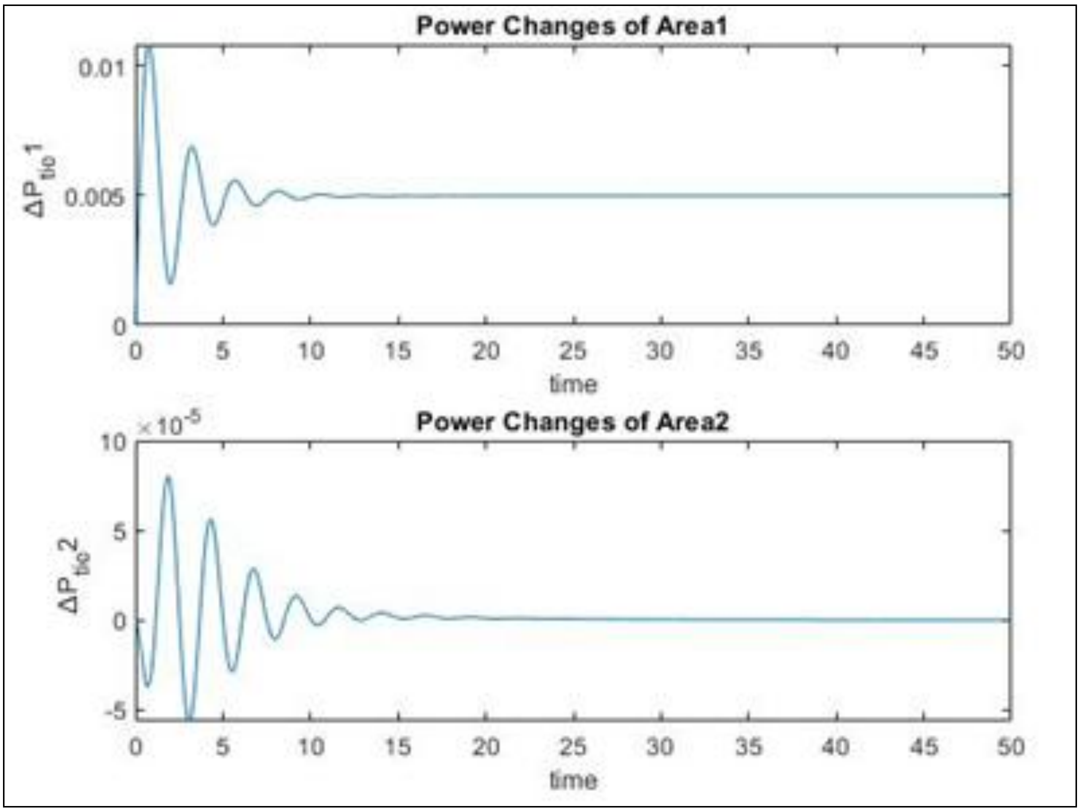

Fig 4: power changes over time for area 1 and 2.

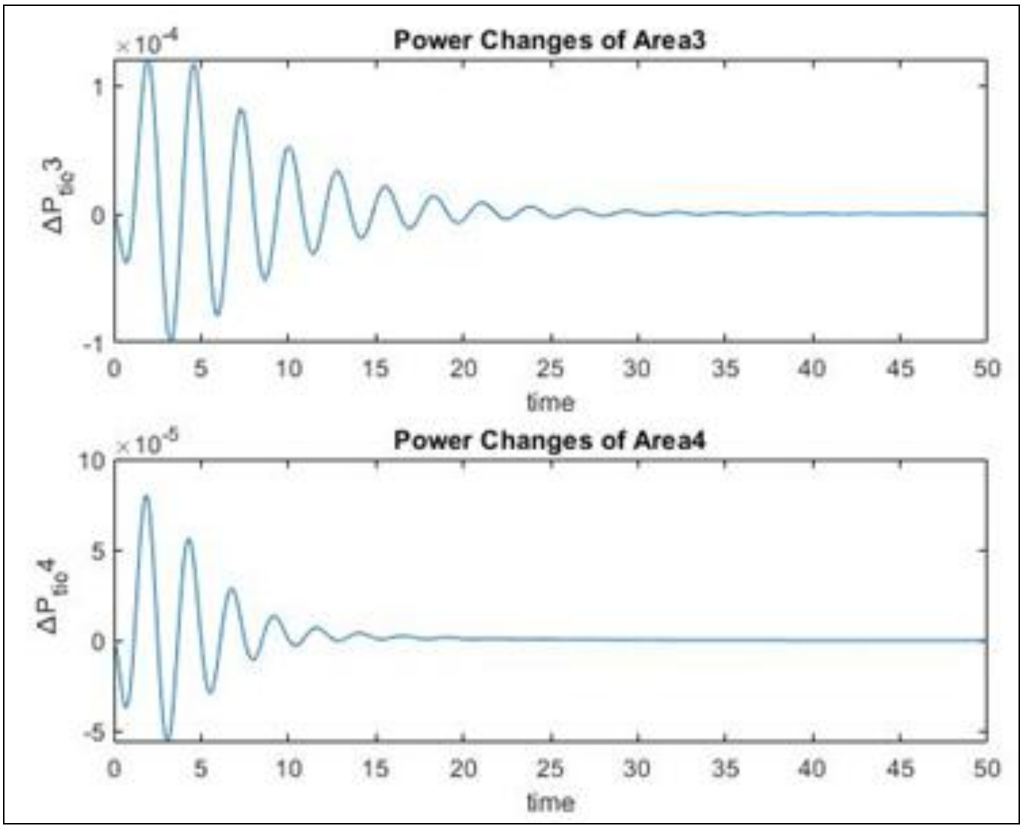

Fig 5: power changes over time for area 3 and 4.

Figure 6 depicts the power changes for the gas-turbine units in area 5 with Non-reheated-turbine units and area 6 with Non-reheated-turbine Hydro-turbine. In area 5, the power gradually increases from zero, with a transient period of approximately 24 sec. Conversely, in area 6, the power follows a similar pattern to area 5. However, it experiences a shorter transient period of approximately 16 sec. before reaching stability.

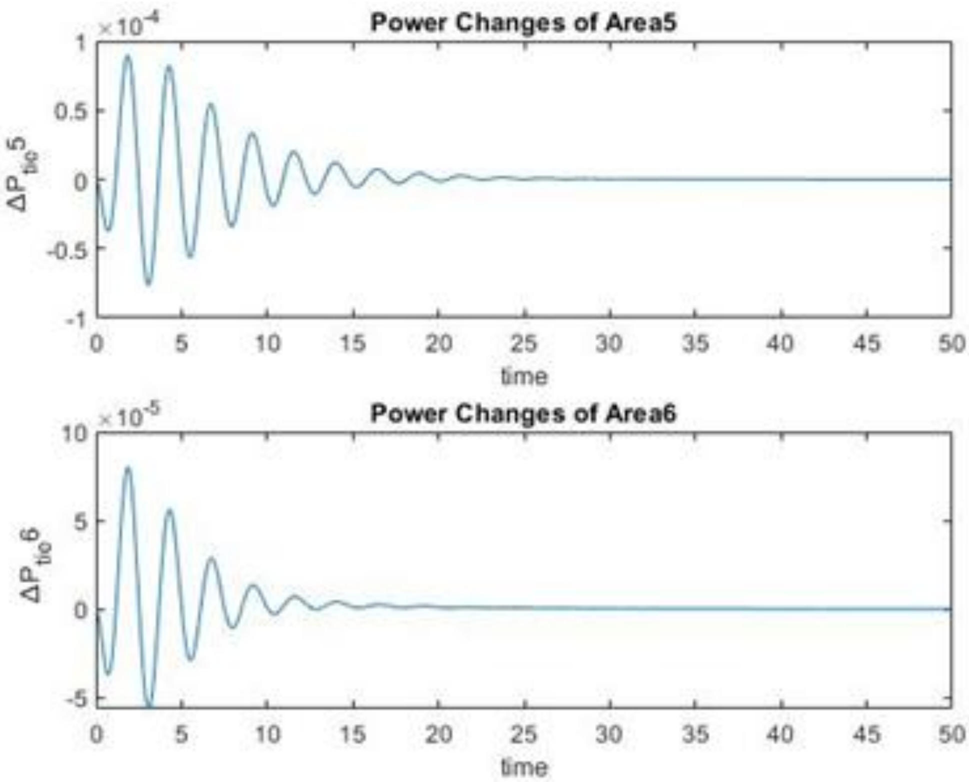

Fig 6: power changes over time for area 5 and 6.

3.1 System results with PID control, ICEFO and ECPO algorithms

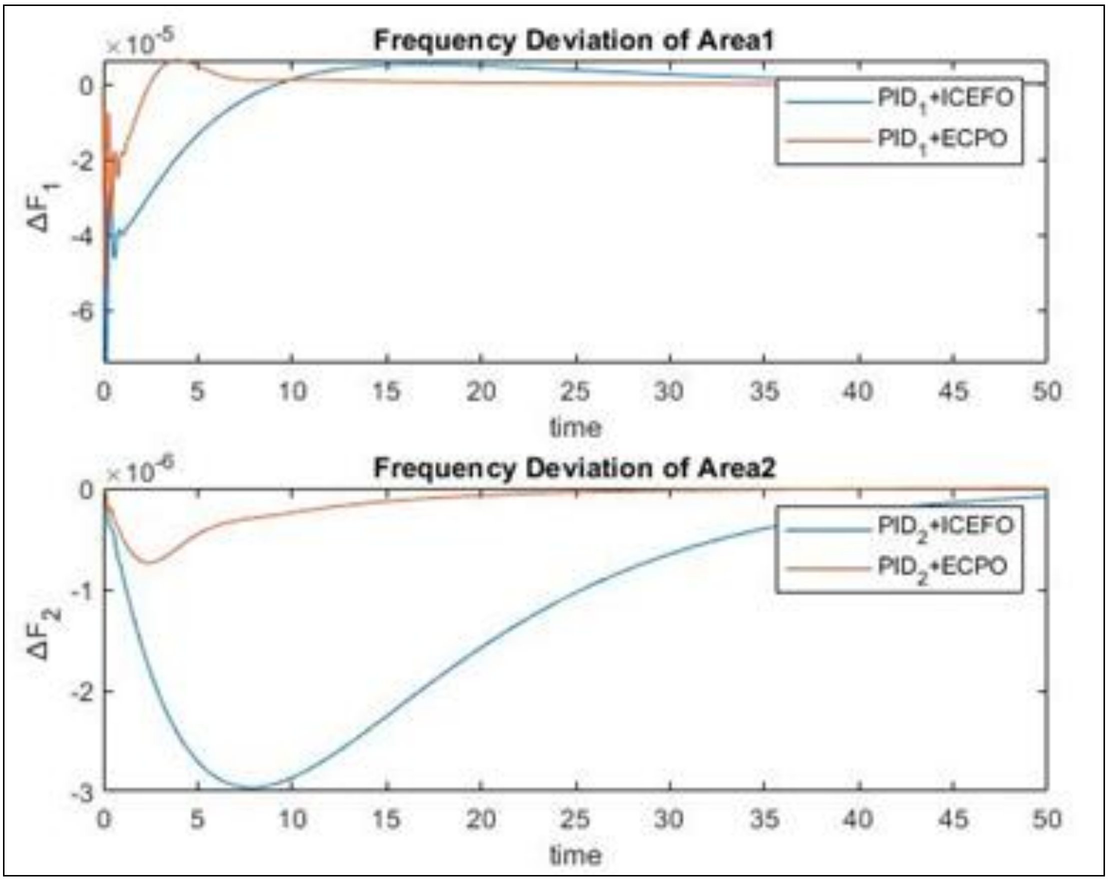

Fig 7: Calculate study results over time for area 1 and 2 using PID, INFO and EXPO.

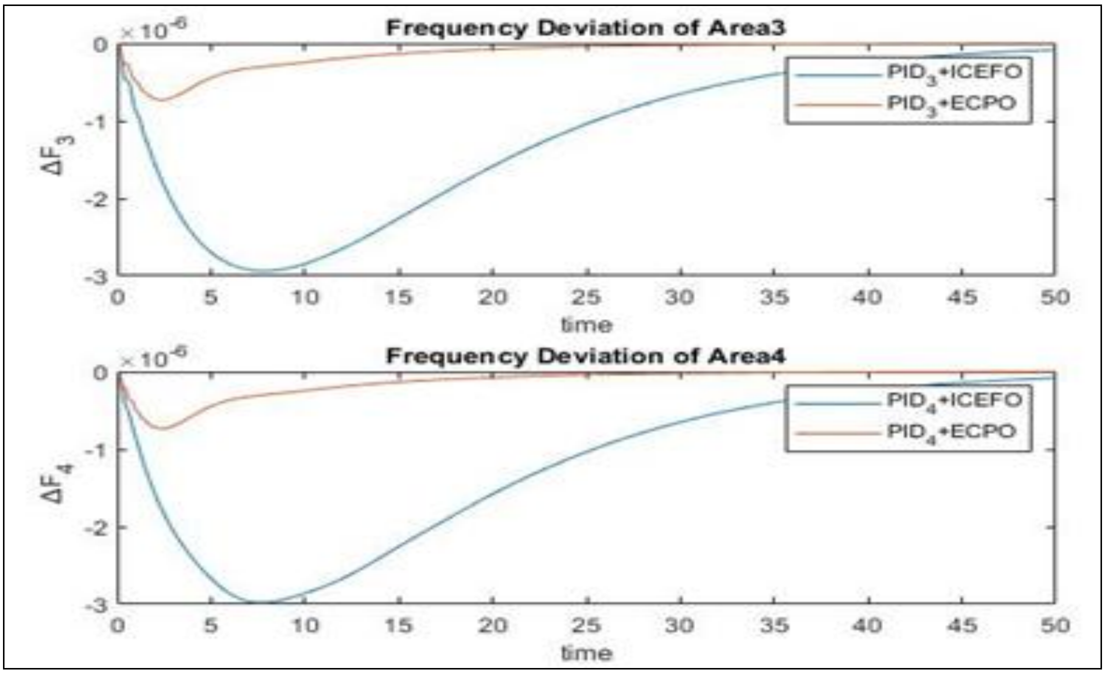

Fig 8: Calculation of the study results according to over time for area 3 and 4

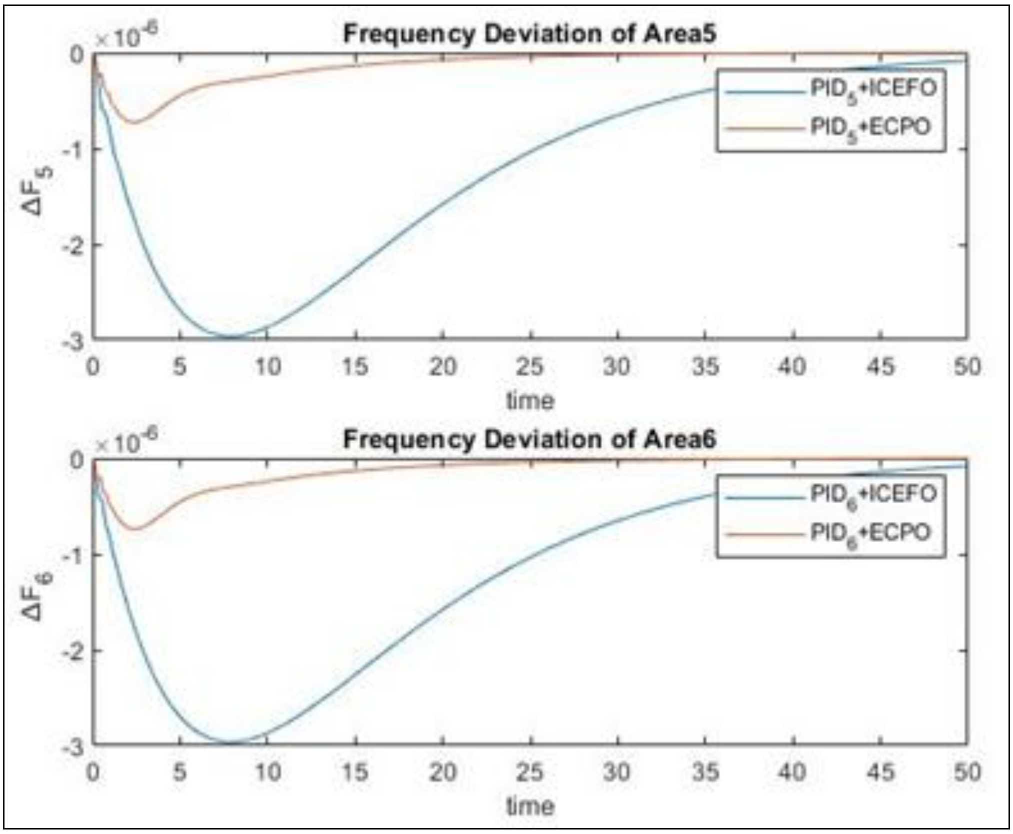

Fig 9: Frequency deviation over time for area 5 and 6 using PID, ICEFO and ECPO.

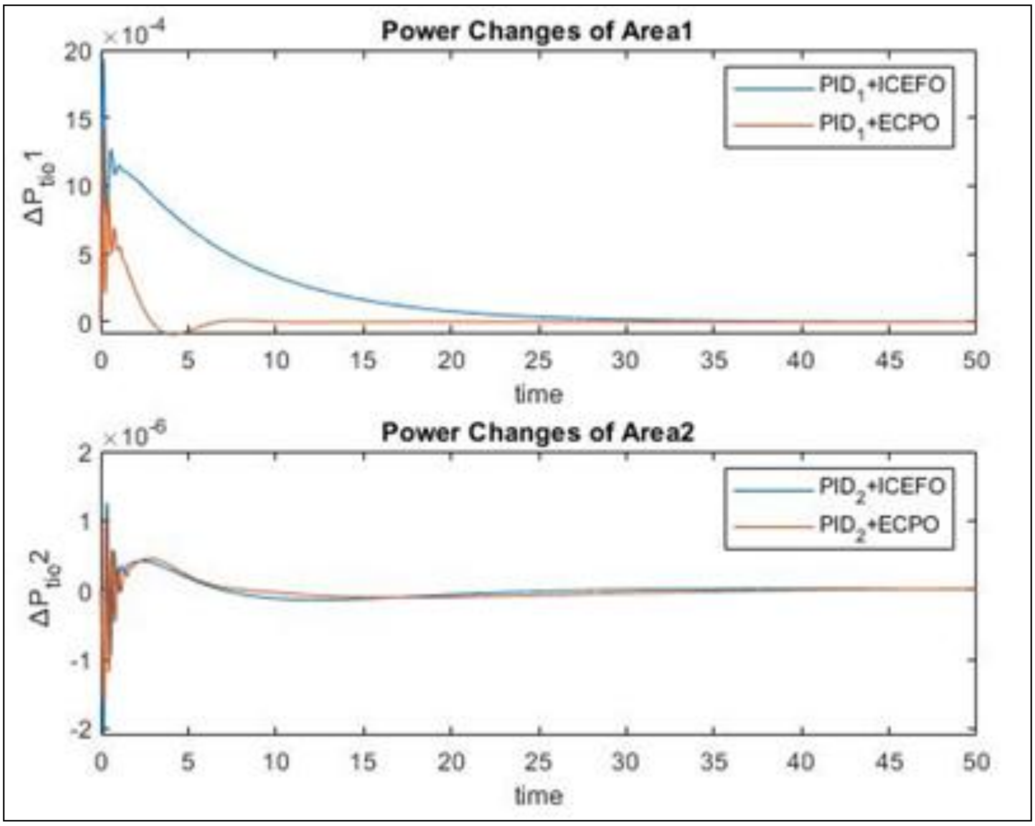

Fig 10: Power changes over time for area 1 and 2 using PID, ICEFO and ECPO.

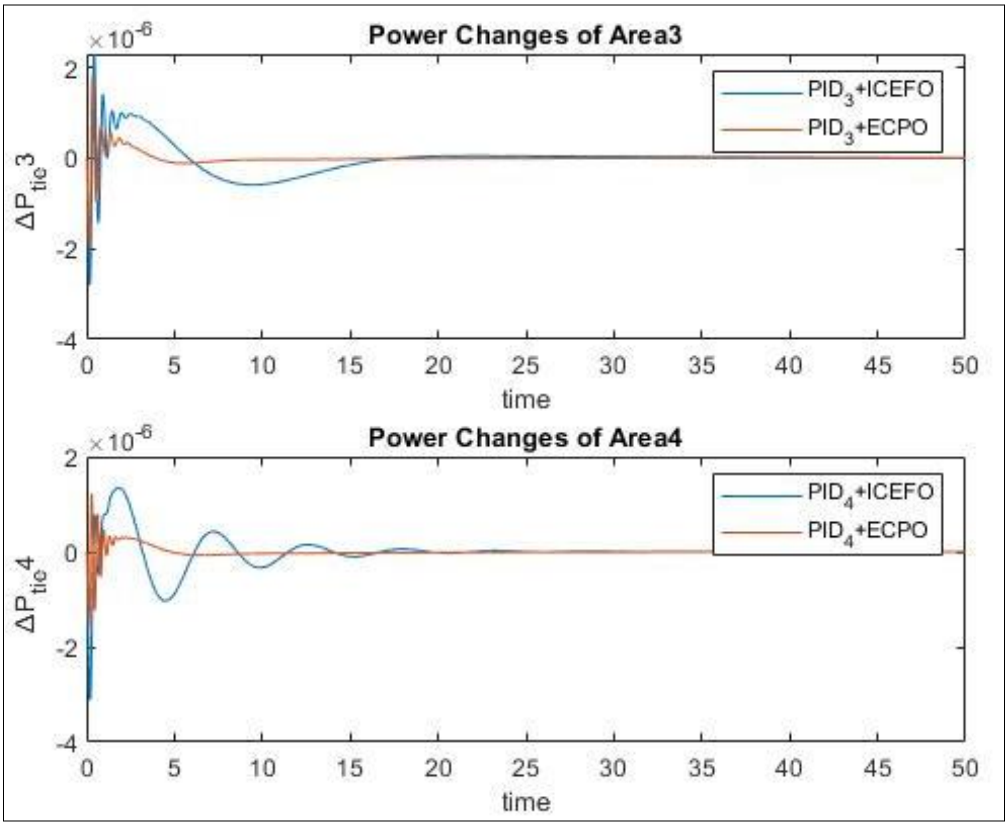

Fig 11: Power changes over time for area 3 and 4 using PID, ICEFO and ECPO.

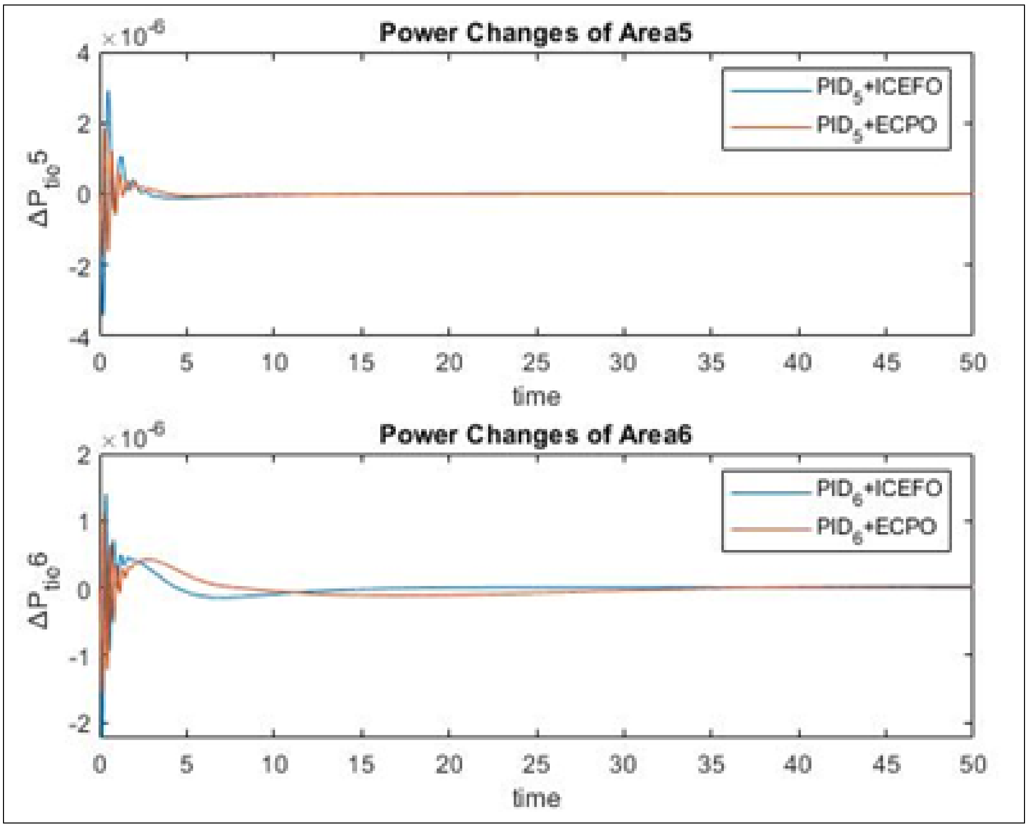

Fig 12: Power changes over time for area 5 and 6 using PID, ICEFO and ECPO.

3.2 Analysis and discussion

This subsection presents the outcomes of the load frequency control system using PID controllers with two optimization methods, ICEFO and ECPO. Three tables are provided: one for PID parameter values using ICEFO, another for PID parameter values using ECPO, and a third for system characteristics comparison. This section analyzes the settling time, overshoot, and undershoot values and discusses how the presence of the controller and the optimization method influence these parameters. It offers insights into the effectiveness of PID controllers and optimization methods in achieving desired system behavior.

Table 3 includes the PID control of each area after applying the ICEFO method to optimize their parameters. where the P value determines the proportional action, the I value handles the integral action and the D value incorporates the derivative action of the PID.

Table 4 lists the PID control of each area after applying the ECPO method to obtain the optimized parameters. Where these tables helps to assess how the optimization algorithms influence the determination of the P, I, and D values for achieving optimal system performance.

Table 3: The parameters of PIDs using ICEFO.

Area	Name	Controller	P	I	D
1	Al-Mansorya	PID_1	6.9758	1.0364	5.7006
2	Al-Quds	PID_2	8.3762	1.0366	8.2022
3	Al-Sadar	PID_3	4.1352	1.8189	9.2896
4	Basmaya	PID_4	1.0362	5.7052	3.7309
5	Wasit	PID_5	8.4949	8.3125	3.6123
6	Hadytha	PID_6	8.9476	4.4681	7.2198

Table 4: The parameters of PIDs using ECPO.

Area	Name	Controller	P	I	D
1	Al-Mansorya	PID_1	10.0472	10.047	10.047
2	Al-Quds	PID_2	0.05582	0.05583	8.5844
3	Al-Sadar	PID_3	9.02291	0.05581	10.039
4	Basmaya	PID_4	4.84672	0.05582	9.7885
5	Wasit	PID_5	9.95071	0.05585	10.0334
6	Hadytha	PID_6	0.09568	0.08364	9.2852

Table 5: A system characteristics comparison.

Area	Name	ΔF	Controller	Settling Time	Overshoot	Undershoot
1	Al-Mansorya	ΔF_1	Without PID	25.5 sec.	-0.2731	-4.1
			PID-ICEFO	34 sec.	0.5344	zero
			PID-ECPO	7.5 sec.	0.5212	zero
2	Al-Quds	ΔF_2	Without PID	35.3 sec.	-0.8731	-1.023
			PID-ICEFO	45 sec.	zero	-3.021
			PID-ECPO	22.6 sec.	zero	-0.9544
3	Al-Sadar	ΔF_3	Without PID	30.2 sec.	-0.962	-1.083
			PID-ICEFO	33.6 sec.	zero	-3.102
			PID-ECPO	20.1 sec.	zero	-9.233
4	Basmaya	ΔF_4	Without PID	30.5 sec.	-0.982	-1.023
			PID-ICEFO	33.6 sec.	zero	-3.102
			PID-ECPO	20.1 sec.	zero	-9.233
5	Wasit	ΔF_5	Without PID	33.4 sec.	-0.9831	-1.0012
			PID-ICEFO	34.6 sec.	zero	-3.004
			PID-ECPO	21.1 sec.	zero	-8.933
6	Hadytha	ΔF_6	Without PID	34.2 sec.	-0.985	-1.0992
			PID-ICEFO	35.6 sec.	zero	-3.005
			PID-ECPO	22.1 sec.	zero	-8.833

4. Conclusion

Using two optimization techniques, ICEFO and ECPO, and six PID controllers, the study investigates the LFC problem in six Iraqi power plants. According to simulation data, ECPO improves system performance and speeds up system stabilization. The method ensures a dependable power supply and prevents system failures by achieving faster settling times and more precise load frequency regulation. All things considered, the suggested control strategy handles LFC issues well.

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