Fuzzy TIDF Controller Design for Deregulated AGC Systems Using Moth-Flame Optimization

K. Alfoni Jose, G Raam Dheep, Tulasichandra Sekhar Gorripotu

Abstract— **This paper deals with the performance of two control area within a deregulated multi source power system. Both the two areas includes thermal and gas units. The proposed controller is cascade combination of the fuzzy controller and the tilt integral derivative controller with filter (fuzzy TIDF). The controller's parameters are optimized using an advanced Moth Flame Optimization Algorithm (MFOA). This work highlights the superior performance of fuzzy TIDF controller in comparison to PID and TID controllers. This assessment is based on the observation of dynamic responses across different controller configurations. This particular study examines the system's behaviour under poolco based and bilateral scenarios. In summary, this paper presents a new Fuzzy+TIDF controller optimized using a MFOA within a two-area system operating in a deregulated context to mitigate the frequencies and tie-line power.**

Keywords— Fuzzy TIDF, Deregulation, Moth Flame Optimization Technique

I. Introduction

This is well known that, the present-day power system growing rapidly to meet the expectations of the consumers. It's one of the primary responsibilities of the electrical engineers to generate sufficient amount of power through various generating stations and distribute to the consumers. As the Government allowing the private entities to contribute in increasing of generation, certainly there will be issues like power quality, voltage control, frequency regulation and tie-line power deviations. Out of all these, a frequency regulation and tie-line power deviation plays a pivotal role in the system reliability. In deregulated scenario, the private entities are encouraged to be part of the generation and they are having liberty to have a contract with anyone to send the power. Individual System Operators (ISOs) should be responsible for keeping the system parameters within the limits. However, always this may not be possible due to unexpected load demands. Hence, Automatic Generation Control (AGC) is the one which take cares about frequency changes and tie-line power changes. AGC helps balance supply and demand in real-time, maintaining grid frequency and ensuring power quality.

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Literature Review

Many authors are analysed various types of models by employing several techniques for the regulation of the frequency. PSO-based controllers for AGC under deregulation have been researched by Jainet al. Because electricity generation and distribution have become more complex and competitive under deregulation, their research attempts to optimize the controller parameters in AGC. Through the use of PSO, they are able to effectively adjust the controller, enhancing AGC's stability and resilience while effectively adjusting to the changing dynamics of deregulated markets [5]. The problem of attaining optimal control in AGC systems is discussed by Sahu et al. By optimizing the TID controller's parameters using the DE technique, the system's robustness and response time are increased. According to the study, this method improves AGC stability and performance by managing frequency deviations and load variations in an efficient manner, which is crucial for preserving system efficiency and dependability [6]. An innovative optimization technique for controlling load frequency control (LFC) in power systems is proposed by the authors of a study on Dynamic Load Frequency Control in Power Systems using a Hybrid Simulated Annealing based Quadratic Interpolation Optimizer. In order to improve the stability and performance of LFC systems—which are essential for balancing power supply and demand and keeping frequency within predetermined bounds—this method combines Simulated Annealing (SA) with a Quadratic Interpolation Optimizer (QIO) [7].

II. Studied Model

In this study, two area four-unit system is considered under restructured scenario where area-1 consists two GENCOs: Thermal and Gas units and area-2 is also with similar configuration. The thermal participated with 70% share and gas unit participated with 30% share and these will be indicated with appropriate area participation factors (apfs). The model also having four DISCOs out of which two are for area-1 and two for area-2. The power drawn from various GENCOs are specified with contract participation factors (cpfs). [8, 9]. The power agreements between GENCOs and DISCOs will be provided in a matrix which is called as Disco Participation Matrix (DPM). The size of DPM is (no. of GENCOs) x (no. of DISCOs). The total system is developed in MATLAB/SIMULINK environment as shown in Fig. 1. This is well known that, the secondary controllers play vital role in minimizing frequency and tie-line power. Here, fuzzy based TIDF controller has developed do said job and its design is shown in Fig. 2. The (3x3) mamdani rule based is involved in designing fuzzy-TIDF controller and the related membership function pattern is provided in Fig. 3.
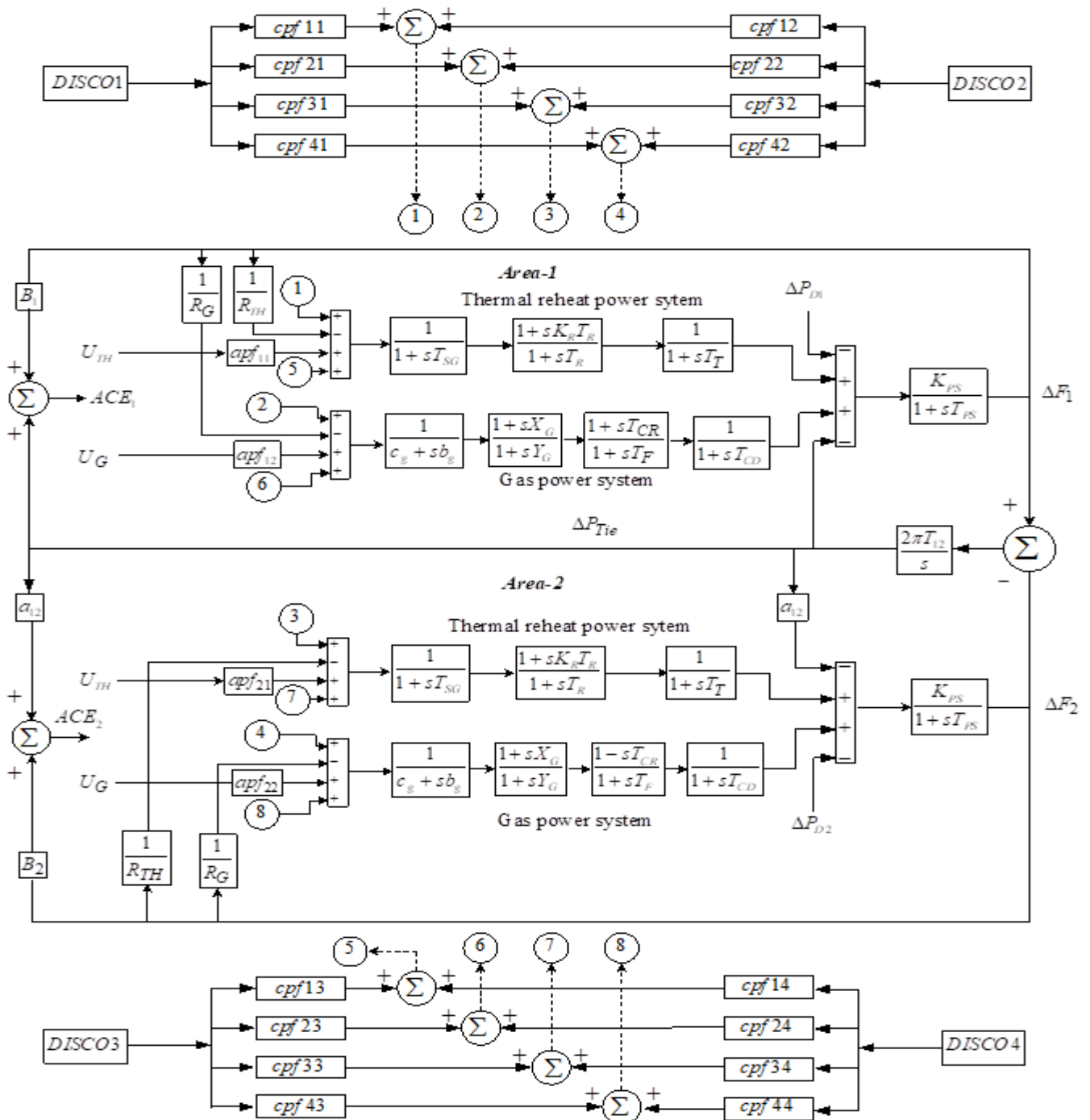
Fig. 1. Four-unit, two-area thermal-gas system in a deregulated setting
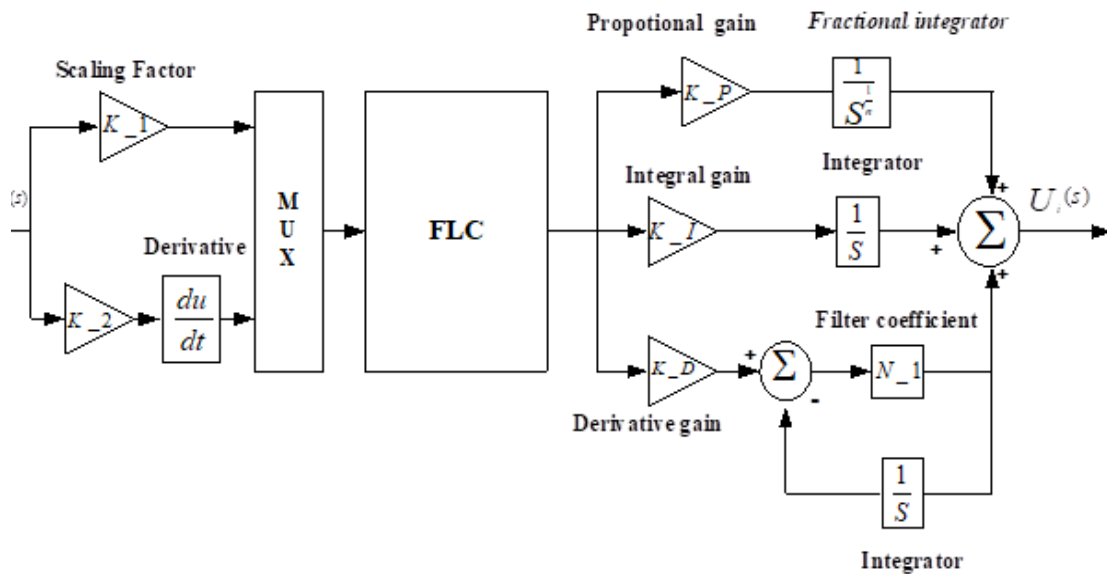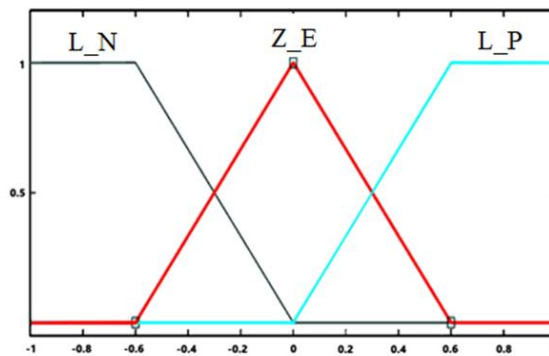
Fig. 2. Design of Fuzzy TIDF

Fig. 3 Membership function

III. Result Analysis

The designed model was studied under two scenarios of deregulation i.e. poolco based and bilateral based scenario. In poolooco based, the DISCOs should have agreement with the GENCOs of within the area. That means, the power transaction should be present within the control area. Whereas, in bilateral based scenario, the DISCOs have choice to have agreement with any GENCOs of any area. These agreements are defined by the following DPMs:

For poolco based:

$$\begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

For bilateral based:

$$\begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix}$$

In first scenario, assume that 10% of step load perturbation (SLP) occurred at DISCOs of area-1 so that there will 20% of SLP will be present at the area-1 GENCOs. The system is analysed with MFO tuned Fuzzy-TIDF controller with provides superior performance while compared to other published results. This controller helps in enhancing the transient stability of the system. The parameters of the controller are tuned employing Moth Flame Optimization (MFO) technique and the process of tuning is explained in [10, 11]. The tuned parameters under both the scenarios are provided in Table 1. The dynamic responses under poolco based are shown in Fig. 4 (a-c) and its related performance indices are provided in Table 2.

Table 2 and Figure 4(a-c) made it clear that the MFO-based TIDF outperforms the others in terms of settling time, peak overshoot and undershoot, and objective function. ISE: 0.0141 in contrast to TLBO: PID (0.0356), TLBO:TID (0.0288), GA:PID (ISE= 0.0935), DE:PID (0.0548), and TLBO-PS (0.0270). In the second case, suppose that 10% of the step load perturbation (SLP) happened at the area-1 and area-2 DISCOs, resulting in 20% of SLP at the area-1 and area-2 GENCOs. Fig. 5 (a-c) displays the dynamic responses under bilateral basis, and Table 3 offers the performance indicators associated with it. It was clear that, in comparison to the others, the MFO-based TIDF offers better indices and a function ISE: 0.0138 with fewer targets.

Table 1: MFO Tuned Fuzzy TIDF controller parameters

Controller Parameters		Poolco Based	Bilateral
Area-1	K_1	1.5809	0.6328
	K_2	1.2342	1.3992
	K_{P1}	4.7139	2.5051
	K_{I1}	4.5413	8.8612
	K_{D1}	6.7573	6.7807
	N_1	495.8219	22.8394
	n_1	8.7510	6.0133
Area-2	K_3	1.1681	1.5231
	K_4	1.2155	1.5248
	K_{P2}	5.6883	9.5211
	K_{I2}	4.4486	2.9107
	K_{D2}	5.3152	4.9533
	N_2	73.7567	134.3776
	n_2	6.7549	6.0352

Table 2: Poolco Based Performance Index

Parameters	Settling times T_S			Peak over shoot (x 10^-2)			Under shoot (x 10^-2)			ISE
	ΔF_1	ΔF_2	ΔP_{Tie}	ΔF_1	ΔF_2	ΔP_{Tie}	ΔF_1	ΔF_2	ΔP_{Tie}	
GA: PID [8]	6.11	6.79	2.40	0.0503	1.38	0.86	-29.16	-11.91	-3.97	0.0935
DE: PID [8]	5.52	4.51	1.88	0.0409	1.20	0.57	-25.74	-9.46	-3.15	0.0548
TLBO: PID [9]	4.83	4.65	1.66	0.0498	1.09	0.51	-24.89	-8.78	-2.92	0.0356
TLBO: TID [9]	4.68	3.40	1.64	0.0432	1.01	0.61	-21.33	-7.91	-2.54	0.0288
TLBO-PS: TID [9]	4.17	1.99	1.64	0.0347	0.56	0.39	-21.55	-7.79	-2.52	0.0270
Proposed MFO: Fuzzy TIDF	4.13	1.91	1.49	0.0136	1.15	0.35	-6.58	-7.64	-0.10	0.0141

Table 3: Bilateral scenario performance index

| Parameters	Settling times T_S			Peak over shoot (x 10^-2)			Under shoot (x 10^-2)			*ISE*
	ΔF_1	ΔF_2	ΔP_{Tie}	ΔF_1	ΔF_2	ΔP_{Tie}	ΔF_1	ΔF_2	ΔP_{Tie}	
GA: PID [8]	12.50	12.64	3.20	14.78	10.36	0.05	-49.49	-20.89	-1.50	0.7348
DE: PID [8]	10.87	11.47	3.08	9.88	6.83	0.05	-46.67	-21.58	-1.86	0.4945
TLBO: PID [9]	9.92	11.42	3.29	7.45	6.5	0.051	-33.52	-32.42	-1.35	0.2017
TLBO: TID [9]	8.58	8.32	5.25	4.12	9.6	0.05	-29.90	-24.9	-1.26	0.0926
TLBO-PS: TID [9]	5.82	6.67	2.53	4.50	3.36	0.05	-25.30	-23.12	-0.64	0.0872
Proposed MFO: Fuzzy TIDF	5.64	6.32	2.36	3.83	3.28	0.05	-5.70	-1.03	-0.03	0.0138
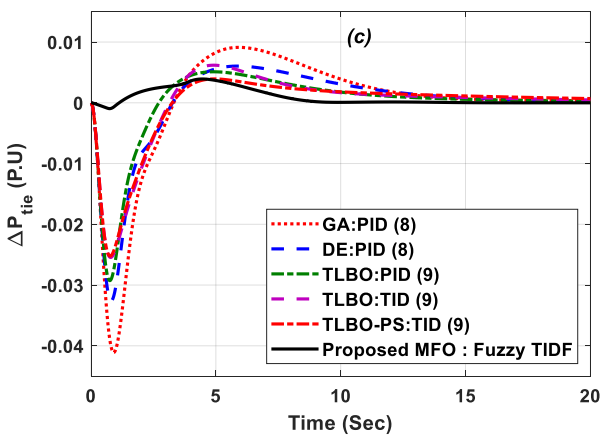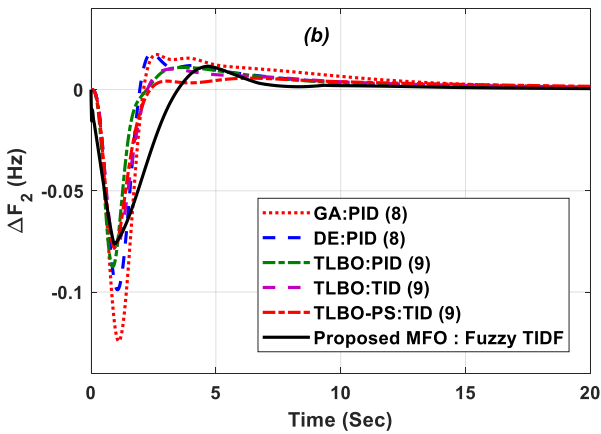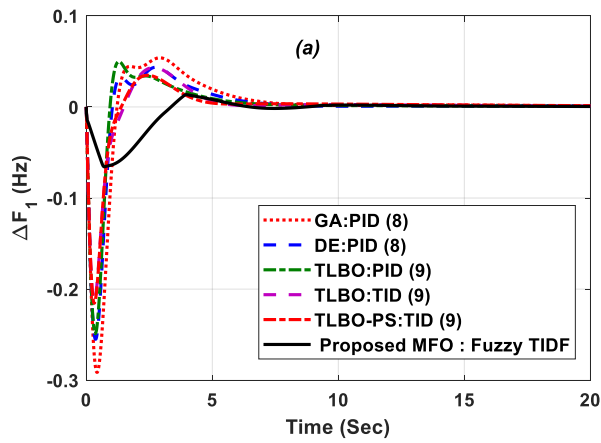
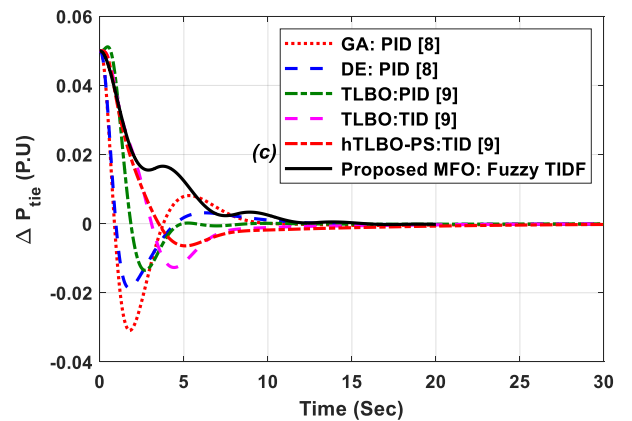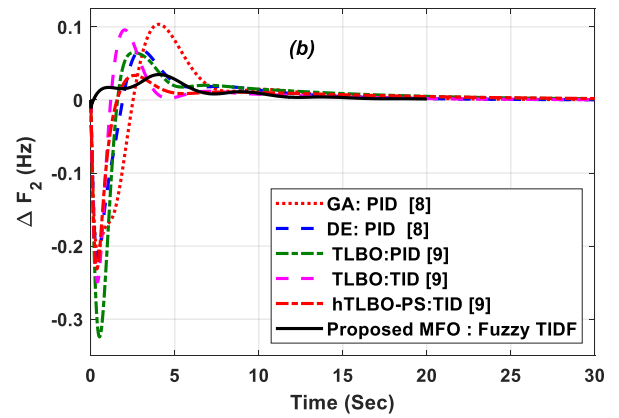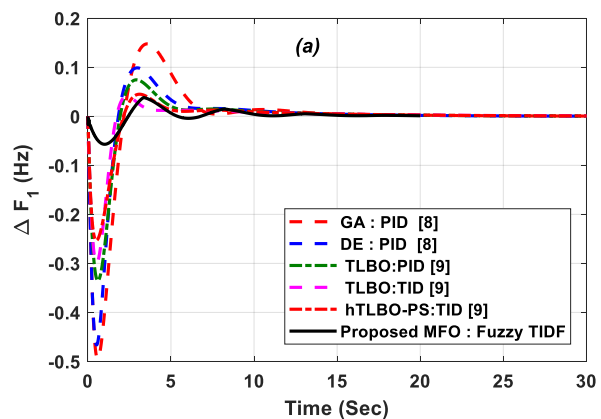**Fig. 4 (a-c)** Responses in a scenario based on poolco

Fig. 5 Responses in a scenario based on bilateral

IV. Conclusion

The fuzzy TIDF controller for Automatic Generation Control (AGC) in a multi-area deregulated power system based on MFO was examined in this study. For the fuzzy controller, two input defuzzifications using 3x3 rule-based analysis were used. Other modern methods, such as GA and DE-based PID controllers, TLBO-based TID and PID controllers, and hTLBO-PS-based TID controllers, are compared to the performance of the MFO-based Fuzzy TIDF controller. The outcomes demonstrate the MFO-based Fuzzy TIDF controller's supremacy. In comparison to the most recent published approaches, it greatly enhances dynamic performance indicators including the goal function, peak over/undershoots, and settling time across all scenarios studied.

Acknowledgment

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