AGC of Multi Area Solar-Thermal System Under Open Market Scenario

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Abstract. A TID controller is developed to address the LFC issue in a restructured electric system that is interconnected across two area Solar-Thermal systems. The SMA is employed to refine the suggested TID controller parameters. The efficacy of the proposed TID controller based on SMA is evaluated using a multi-area inte-rconnected electric system. The proposed controller also considers system non-linearities, including GDB and GRC. The simulation observations indicate that the suggested TID controller utilizing SMA greatly enhances system frequency stability across various load perturbation situations.

Keywords: Load Frequency Control (LFC), Slime Mould Algorithm (SMA), Tilt Integral Derivative Controller(TID) , Deregulated System.

1. Introduction

LFC is an essential element in the management and regulation of electric power systems. As total generation and reported power consumption persistently diverge in frequency, generation, and tie-line power, all deviate from their designated line power levels. The principal aims of an Automatic Generation Control (AGC) system are to swiftly uphold the designated frequency levels and enable power exchange with neighbouring control areas. Our principal objectives are to maintain the system's frequency and guarantee that the tie-line power fluctuations remain within the required parameters [1-4]. Traditionally, a power system was managed by a singular entity referred to as a vertically integrated utility (VIU), which oversaw all facets of generation, transmission, and distribution. This specific VIU exploited its monopoly to supply power at regulated rates, providing clients with no alternative choices and leading to a significant price disparity. Numerous researches on conventional power systems, encompassing hydro and thermal energy, have been undertaken throughout the years. The authors accomplished LFC in electrical

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systems, although they omitted any discussion on deregulated electrical networks [5–8]. The deregulation of the electricity industry has substantially altered the government's incentives and directives for organizations regarding their operational management and control. The automated generation control (AGC) is a supplementary system that efficiently regulates production by rectifying frequency and output discrepancies, hence assuring stable and dependable operation [9-12].A fuzzy-controlled genetic algorithm (FCGA) is employed in a restructured context to accomplish load frequency control (LFC) of the hydrothermal system. Traditional controllers possess limitations that artificial intelligence technology adeptly addresses. The formulation of the Load Frequency Control (LFC) problem is influenced by the introduction of transmission access and the rise of socially-oriented enterprises involved in electricity generation, transmission, and distribution [13]. A single-area power system with several power sources is utilized to examine the dynamic response to minor load disturbances. Hydroelectric power generation use speed governor control, whereas thermal and gas power generation utilises proportional-integral (PI) load frequency management [14]. The settings of the PI controller are optimised to provide stability in a single-area LFC system with time delay using a graphical method. The location of the stability boundary is essential to the methodology. The accuracy and efficacy of the proposed technique are illustrated through time-domain simulations. The stability area is illustrated in the controller parameter space [15]. The notion of fuzzy gain scheduling for PI controllers is employed to regulate load frequency in multiple power systems [16-17].A PID controller is employed to regulate AGC in multi-area systems. Various techniques, including as Firefly, GSA, PSO, and HGS, have been investigated to optimize controller settings [21–24]. These techniques lead to premature convergence instead of the They have not evaluated the algorithm's robustness under a variety of conditions, and they have not anticipated global optima. When the system demonstrates considerable dynamics, the control advantages derived from the aforementioned methods are inadequate in mitigating the system error [25].

2. Deregulated Multi Area System

A deregulated multi-area power system refers to an electricity grid spread across multiple regions or areas, operating in a deregulated market environment. In such a system, the traditional monopoly of vertically integrated utilities is replaced with competitive market structures. This allows multiple entities to participate in the generation, transmission, and distribution of electricity, fostering efficiency, innovation, and consumer choice. Fig 1 shows the block diagram of multi area system. In the electrical sector, deregulation is the process of altering the laws and regulations that govern corporate operations to provide consumers a choice of energy providers. In a deregulated electrical market, energy suppliers and customers are free to use their funds however they see appropriate for the upkeep and enhancement of transmission and power producing infrastructure.

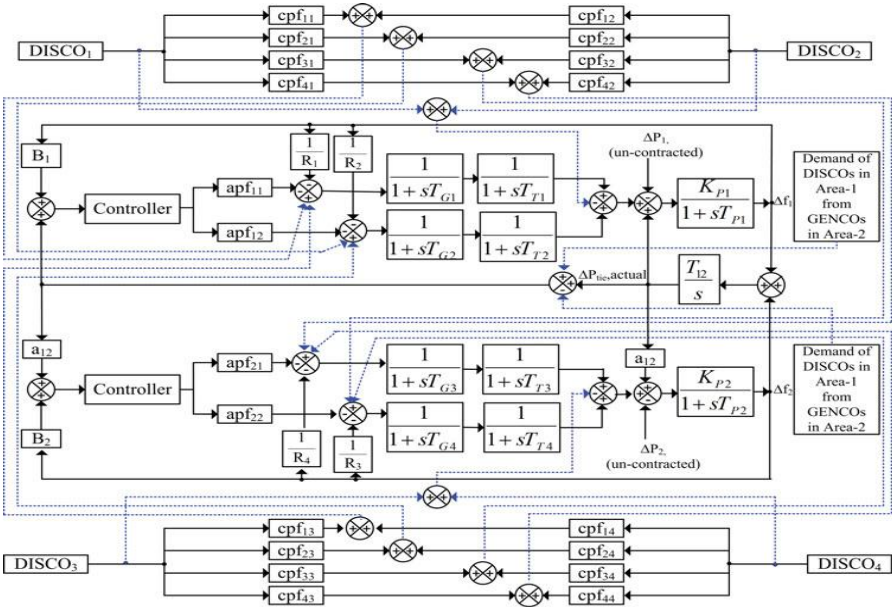


Fig. 1. Block diagram of multi area power system

3. Design of Various Controllers

A **TID Controller** is a type of feedback controller used in control systems to improve system performance by combining three key components: **Tuning (T)**, **Integral (I)**, and **Derivative (D)** actions. It is similar to a traditional PID controller, but the inclusion of the tuning parameter adds flexibility, allowing for more precise control in certain applications .Fig 2 represents the block diagram of TID controller.

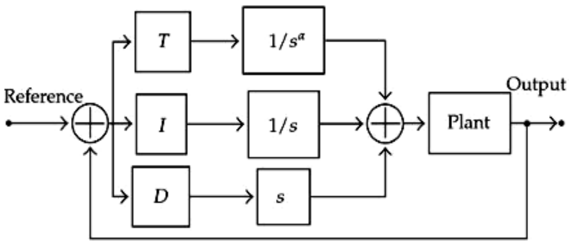


Fig. 2. Block diagram of TID Controller

The desired function is expressed as:

$$ISE = \int_{0}^{t_{sim}} (\Delta f_1)^2 + (\Delta f_2)^2 + (\Delta P_{Tie})^2 \cdot dt \quad (1)$$

4. Slime Mould Algorithm

The Slime Mould Algorithm (SMA) is a Meta heuristic optimization technique inspired by the foraging behavior of slime moulds, specifically their efficient path finding and nutrient distribution strategies. Slime moulds, simple single-celled organisms, exhibit remarkable intelligence in exploring their environment and optimizing resource collection, which provides the biological foundation for the algorithm. Fig 3 shows the flow chart of SMA algorithm.The SMA method adheres to three primary principles: grabble, wrap, and approach. Grabble inhibits molecular collisions during the process of food acquisition. The grab phenomena exhibit equivalent velocity to that of viscous structures.

1 Approach food

In order to mathematically represent the way slime mould approaches, a proposed rule is suggested to simulate the contraction mode:

$$\overrightarrow{X(t+1)} = \begin{cases} \overrightarrow{X_b(t)} + \overrightarrow{vb} \cdot \left(\overrightarrow{W} \cdot \overrightarrow{X_A(t)} - \overrightarrow{X_B(t)}\right), r < p \\ \overrightarrow{vc} \cdot \overrightarrow{X(t)}, r \geq p \end{cases} \quad (2)$$

2 Wrap food:

The mathematical equation for updating the position of slime mould is as follows:

$$X^* = \begin{cases} rand \cdot (UB - LB) + LB, rand < z \\ \overrightarrow{X_b(t)} + \overrightarrow{vb} \cdot \left(W \cdot \overrightarrow{X_A(t)} - \overrightarrow{X_B(t)}\right), r < p \\ \overrightarrow{vc} \cdot \overrightarrow{X(t)}, r \geq p \end{cases} \quad (3)$$

3 Grabble food:

The magnitude of vector $\overrightarrow{vb}$ fluctuates randomly within the range of [-a,a] and progressively tends towards zero as the number of iterations increases. The vector $\overrightarrow{vc}$ fluctuates throughout the range of [-1,1] and gradually approaches zero. The mechanism through which agents adjust their positions in the search space, being guided toward promising solutions. It mimics the slime mould's foraging intelligence, enabling the algorithm to solve complex optimization problems effectively.

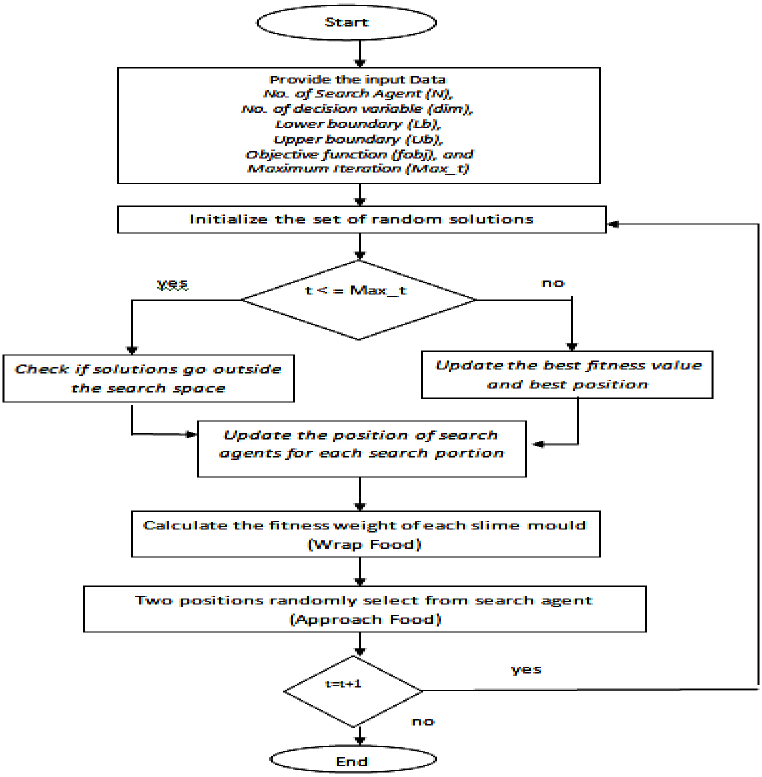


Fig. 3. Flowchart of SMA-algorithm

5. Results And Discussions

Deregulated power systems comprise solar-thermal systems in each region. Each region has been exposed to a load disturbance of 0.01 pu.

Case A: Pool Based Transaction :

A Pool based transaction is the term used to describe the outcome of collaboration between distribution companies (DISCOs) in the same area and any generation companies (GENCOs) in the same region. Fig 4 (a) ,4 (b) and 4 (c) presents the deviation of area-1 , area-2 frequency and tie line power utilising various SMA-based and controllers. The SMA-based TID controller demonstrates superior performance compared to the PI,PID controllers in the context of a pool co-based transaction shown in Table 1.

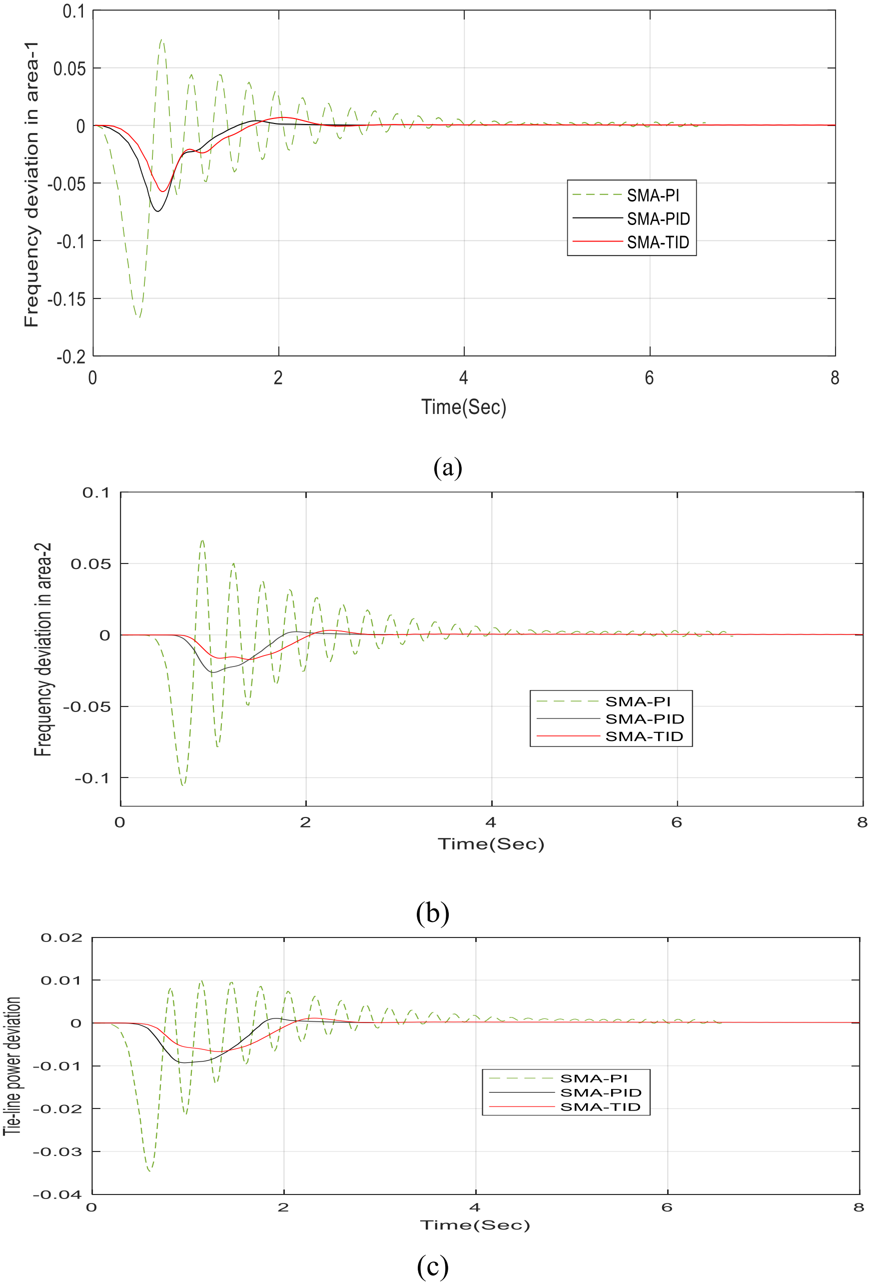


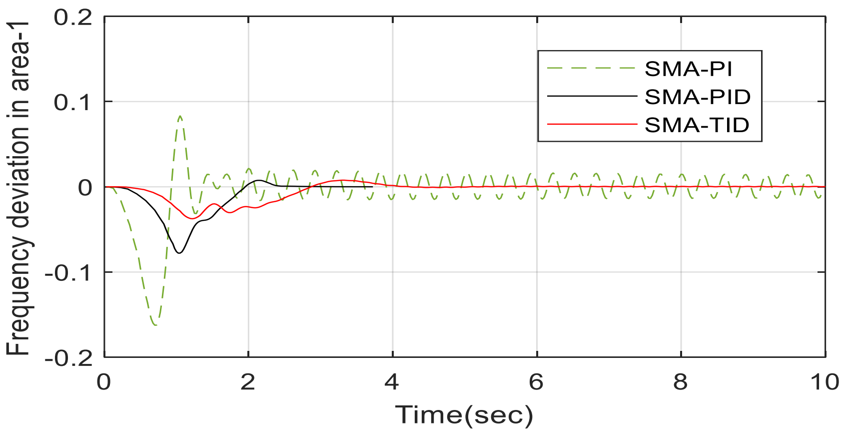
Fig. 4. Time response characteristics plots for SMA algorithm (a) Δf_1 (Hz), (b) Δf_2 (Hz), (c) ΔP_{tie12} (pu MW)

Table 1. Transient performance characteristics of various controllers using SMA algorithm

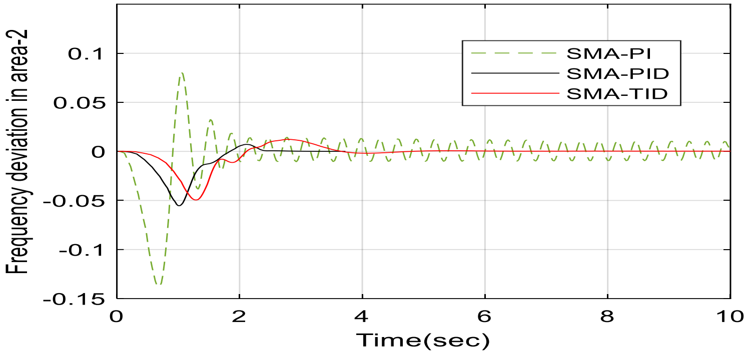
S.No	PO			PU			ST		
	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}
SMA-PI	0.08	0.07	0.01	0.18	0.12	0.034	5.6	5.8	5.8
SMA-PID	0.003	0.0032	0.0012	0.07	0.03	0.009	2.6	2.8	4.4
SMA-TID	**0.002**	**0.0028**	**0.0009**	**0.0058**	**0.017**	**0.0062**	**3.8**	**4.2**	**4.2**

Case B: Bilateral Transaction:

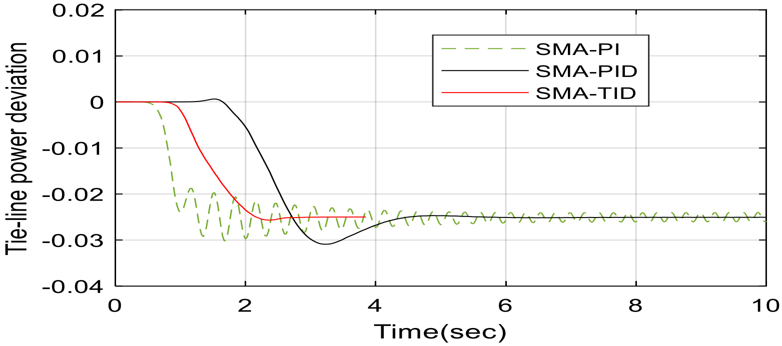
A transaction in which Distribution Companies (DISCOs) distribute the load with Generation Companies (GENCOs) from another area is referred to as a bilateral transaction. Fig 5 (a) ,5 (b) and 5 (c) presents the deviation of area-1 , area-2 frequency and tie line power utilizing various SMA-based and controllers. The SMA-based TID controller demonstrates superior performance compared to the PI, PID controllers in the context of a bilateral -based transaction in Table 2.



(a)



(b)



(c)

Fig. 6. Time response characteristics plots for SMA algorithm (a) Δf_1 (Hz), (b) Δf_2 (Hz), (c) ΔP_{tie12} (pu MW)

Table 2. Transient performance characteristics of various controllers using SMA algorithm

S.No	**PO**			**PU**			**ST**		
	Δf_1	**Δf_2**	**ΔP_{tie}**	**Δf_1**	**Δf_2**	**ΔP_{tie}**	**Δf_1**	**Δf_2**	**ΔP_{tie}**
SMA-PI	0.08	0.08	0.0008	0.17	0.13	0.03	5.8	6.8	6.2
SMA-PID	0.003	0.002	0.0006	0.08	0.06	0.032	4.8	6.2	5.4
SMA-TID	**0.015**	**0.016**	**0.005**	**0.038**	**0.052**	**0.031**	**4.6**	**5.8**	**4.8**

6. Conclusions

The network load demand is a challenge to resolve in the power system as it requires the creation of several ideal controllers. The controller's principal duty is to swiftly regulate a consistent frequency while simultaneously managing the voltage magnitude. To address the challenges presented by LFC, several optimal controllers have been developed. The objective of this research is to assess the effectiveness of the TID controller in a deregulated environment for a variety of power-based transactions. Across all loading conditions, the SMA-tuned TID controllers outperform the PI and PID controllers in terms of expedited settling time and minimized peak undershoot and overshoot.

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