Load frequency control of multi area system under deregulated environment using artificial gorilla troops optimization

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Article Info

ABSTRACT

The artificial gorilla troops method is utilized in the tilt integral derivative (TID) controller that is discussed in this paper in order to adorn the load frequency control (LFC) in the restructured thermal-hydal system. The controller is implemented in simulink. In this study, a mathematical definition of the social life of gorillas and innovative methods for exploring and exploiting gorilla habitats are presented. By applying step load perturbations and using integral square error as the evaluation method, the dynamic properties of the system can be determined. It is clear that the newly developed method of optimizing artificial gorilla troops performs better than the grey-wolf optimization technique (GTO). In this paper, the TID controller and the proportional integral derivative (PID) controller are contrasted with regard to a variety of optimization strategies inorder to compare different power transcations.

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1. INTRODUCTION

Each electrical plant must maintain a continual eye on the fluctuating demand for energy throughout the day in order to be able to fulfil the excessive demands for excellent service from its consumers, which are increasing all the time. As a result, load changes are utilised to reduce output power fluctuations at various points during the day because it is not possible to maintain a stable energy supply at all times. In the prevailing state of affairs, one of the most fundamental needs is to maintain a reliable and cost-effective electricity supply while presenting and dispensing power in a linked instrument as reliably and cost-effectively as feasible. While load disturbances have a significant impact on the frequency of machine electrical delivery, reactive electricity varies in reaction to variations in voltage and present day conditions. In addition, when more and more regions are connected to one another by tying traces, the shape of the community will become increasingly complex. Even if the frequency is reduced by a small amount, the magnetising current will continue to increase in intensity as the frequency is reduced. As a consequence of the increasing current that runs through it, the transformer may become saturated, and the coil may become burned out. Because of the increased demand for electricity, maintaining a balanced electric grid is difficult in today's environment. A continuous conversion of weight occurs throughout the functioning of electrical equipment. This device's major function is to ensure that the required degree of strength and stability is maintained in the electric device. There is a negative relationship between the mechanical output strain of the generator and the frequency of the tool [1]-[4].

Because of the deregulation of the electrical industry, there has been a considerable shift in the incentives and indicators supplied by the government to organisations for controlling and managing their operations. Electric utilities, which comprise generation companies (GENCOs), transmission companies (TRANSCOs), and distribution companies (DISCOMs) as part of the DISCO tool, have been liberalised as a top-tier employment that is now open to anyone who wants to work in the industry. An independent system operator (ISO), which is a large corporate enterprise, is responsible for keeping track of consumers in the open market. Despite the fact that they are no longer monitored, the greater part of VIU's auxiliary services will continue to perform a specialised purpose in the real-time energy market, despite the fact that they are no longer monitored. When it comes to handling production, an auxiliary carrier known as automated generation control (AGC) is responsible for removing frequency and output irregularities while also maintaining reliable operation [5]-[7]. AGC systems will continue to play a crucial role in the management of out-of-control electric power networks, regardless of the outcome. AGC structures will almost certainly continue to be important in unregulated electric systems; however, the operations of AGC systems in a vertically integrated agency and those in an unstructured device differ significantly in some ways [8]-[10]. A large number of researchers have discovered a range of solutions to the problem of controlling the charging frequency of batteries in an out of control environment. Based on the work of the fundamental elements of conventional algebraic geometric computation are the proportional, integrals, and derivatives, as well as their combinations. Proportional integral derivative (PID) is the most frequently used load frequency control (LFC) manipulation [11]–[15], in part because of its simplicity, dependability, and wide range of applications. Nonlinear parameters include the governor dead band (GDB) and generation rate constraint (GRC) that has an impact on the performance of LFCs [16]–[18]. When confronted with LFC stressful events, a number of recent replies were supplied that allowed you to improve the dynamic behaviour of the system. Different optimization algorithms proposed under deregulation [19]-[26]. Many researchers were concerned about the overall performance of PID and tilt integral derivative (TID) controllers in the LFC when it came to evaluating the controllers' overall performance [27]-[29].

The paper is organized as follows: section 2 illustrates the multi-area system model and its main components. Section 3 illustrates the design of TID controllers. Section 4 discusses the artificial gorilla troop's optimization algorithm and mathematical equations. In section 5, the simulation results, obtained following several tests related to the performance of different optimized controllers, are explained and analyzed. At the end, conclusions are presented in section 6.

2. DEREGULATED MULTI AREA SYSTEM
2.1. Deregulated energy system
When used in the context of the electrical sector, the term deregulation is a term used to describe the process of modifying the rules and regulations that govern the business operation in order that consumers have a choice of energy companies from which to select. In a deregulated electrical zone, customers and energy dealers are free to spend their money on the maintenance and expansion of electricity generation and transmission systems as they see fit. The electricity generated through the use of the genco assets is distributed in large numbers through the use of the retail utilities infrastructure. Customers benefit from the ability to compare fees and services as well as through the use of probability-based methodologies.

2.2. Discoparticipation matrix
The AGC system's present scenario has two areas with two power plants, namely the thermal and hydra units as shown in Figure 1. These two areas are separated into two groups, with two GENCOs and DISCOMS in each. The sum of the values for each component in each column of the disco participation matrix (DPM) must equal unity in order for Genco to give the needed load to the disco independent of area or condition.

$$DPM = \begin{bmatrix} cpf_{11} & cpf_{12} & cpf_{13} & cpf_{14} \\ cpf_{21} & cpf_{22} & cpf_{23} & cpf_{24} \\ cpf_{31} & cpf_{32} & cpf_{33} & cpf_{34} \\ cpf_{41} & cpf_{42} & cpf_{43} & cpf_{44} \end{bmatrix}$$
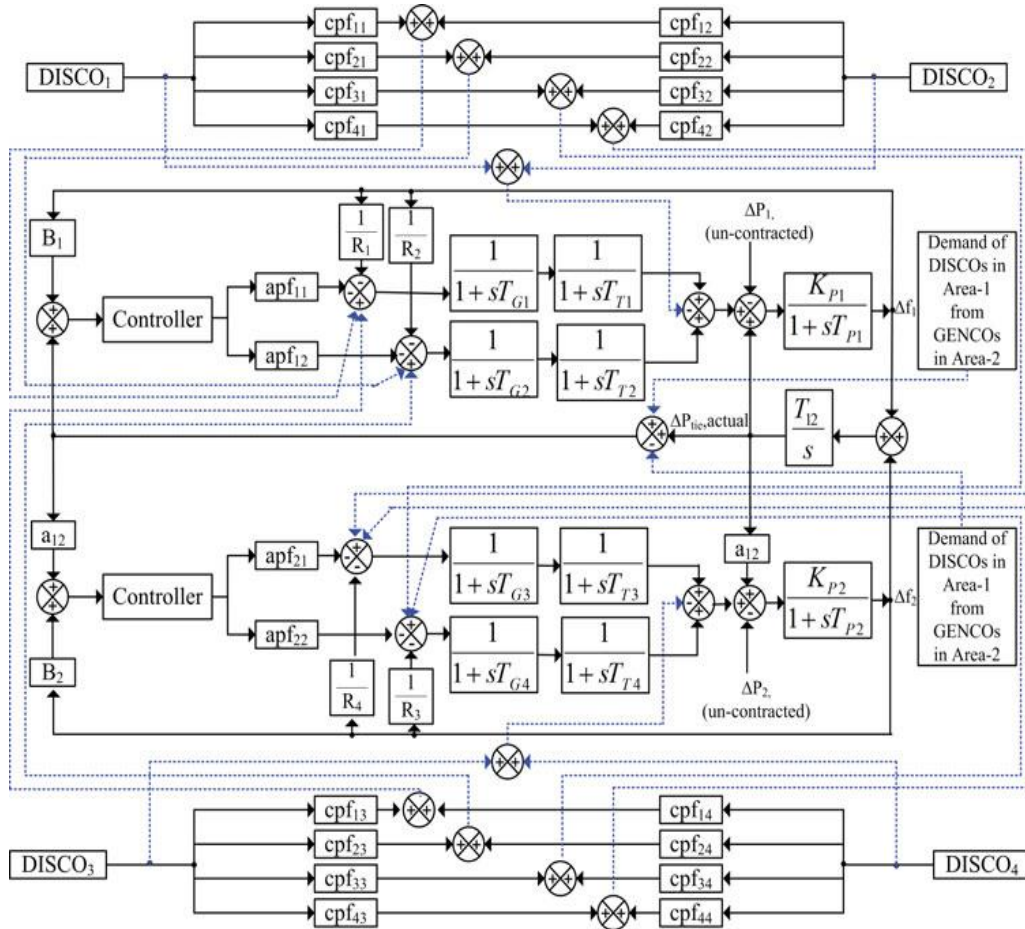
Figure 1. Deregulated multi area system

3.   DESIGN OF CONTROLLERS

In the event of an unexpected load interruption, it is advised that the LFC can be utilised to (1) minimise frequency errors to zero and restore the related power deviation to its forecast value, as described above. Regular LFC controller tuning is required in order to get the desired effects, and this can be performed through the use of a number of different evaluation methodologies using TID controller as shown in Figure 2.
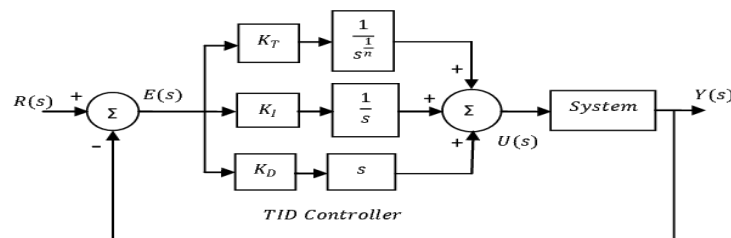
$$T.F(TID) = KT(1/s)^\wedge n + KI/S + KDS$$

Figure 2. TID controller block diagram

The expression of the objective function is:

$$ISE = \int_0^{t_{sim}} (\Delta f_1)^2 + (\Delta f_2)^2 + (\Delta P_{Tie})^2 \cdot dt \tag{1}$$

In the case of each controller, it is possible that the lowest value will be -2, the highest value will be 2, and the n will be somewhere in between (2, 3).

4.   ARTIFICIAL GORILLA TROOPS OPTIMIZATION

Artificial gorilla troops optimization (AGTO), a new meta heuristic set of rules based entirely on gorilla organization behavior, in which specific mathematical processes are described element by element as a fantastic manner in order to actually provide an explanation for the difference many times between the two degrees of exploration and exploitation (exploration and exploitation, respectively) as shown in Figure 3. The AGTO strategy, which is completely based on the gorilla, makes use of five great operators to adopt optimization operations (exploration and exploitation) in order to capitalise on the destination path outcomes and achieve maximum efficiency.

a.   There are three types of answers in the optimization area of the AGTO technique, where X denotes the position vector of the gorillas and GX denotes the gorilla candidate role vectors that have been well-established in each segment, which are used if they outperform the remarkable answer within the optimization area. In the end, the silverback is the consistency of the quality response with each and every repetition of the approach.

b.   There is only one silverback in the entire population when compared to the large number of seeking agents that have been selected for optimization procedures.

c.   In nature, gorilla social behaviour is accurately reflected by three extraordinary solutions: X, GX, and silverback, each of which is unique in its own way.

d.   In addition, gorillas can benefit from increased electricity by discovering more abundant food resources or by building a strong and trustworthy organization. According to the GTO set of principles, solutions are advanced with each repetition, which is referred to as GX. It is the case that a new answer (GX) is determined that it replaces the current one (X). Otherwise, it will almost certainly be kept (GX).

e.   Gorillas are not able to survive on their own, as they prefer to be in groups of people. Consequently, they continue to hunt for food in groups and live under the direction of a silverback that is in charge of all decisions pertaining to the institution. The gorillas attempt to migrate as far away from the poorest solution (the silverback) as possible in order to improve the standing of all gorillas. This is based on the premise that the weakest member of the group symbolises the population's worst answer.
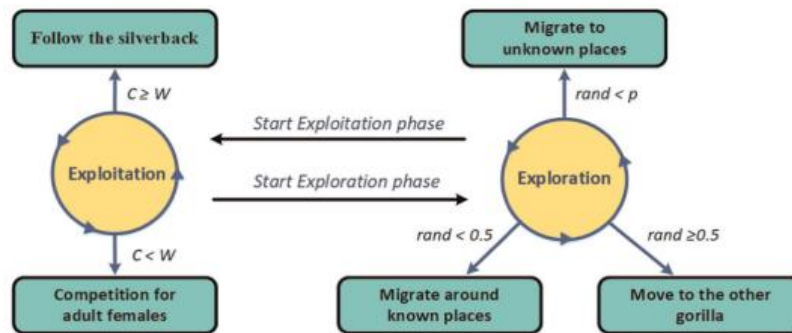

Figure 3. Flowchart of AGTO algorithm

4.1. Exploration phase

The first mechanism allows the algorithm to monitor the whole problem space effectively; the second mechanism increases AGTO exploration performance; and the third mechanism supports the AGTO's ability to escape from local optimum spots.

$$GX(t+1) = \begin{cases} (UB - LB) * r_1 + LB, rand < p \\ (r_2 - C) * X_r(t) + L * H, rand \geq 0.5 \\ X(i) - L * (L * (X(t) - GX_r(t)) + r_3 * (X(t) - GX_r(t))), rand > 0.5 \end{cases} \quad (2)$$

$$C = F * (1 - \frac{It}{MaxIt}) \quad (3)$$

$$F = COS(2 * r_4) + 1 \quad (4)$$

$$L = C * l \quad (5)$$

$$H = Z * X(t) \quad (6)$$

$$Z = [-C, C] \tag{7}$$

4.2. Exploitation phase

During the exploitation phase of the AGTO algorithm, two behaviours are used: follow the silverback and the other males competing for the mature females. A group of gorillas is led by a silverback, who is responsible for making all of the group's decisions, directing the group's movements, and leading the gorillas to sources of food. It is also accountable for the health and safety of the group, and the other gorillas in the group are required to comply with any choices made by the silverback. On the other hand, the silverback gorilla can grow weak and old as it ages, and it might even pass away. If this happens, the black-backed gorilla in the group might take over as the group leader, or other male gorillas might fight with the silverback gorilla and gain authority over him.

$$GX(t + 1) = L * M * (X(t) - X_{silverback}) + X(t) \tag{8}$$

$$M = \left(\left\| \frac{1}{N} \sum_{t=1}^{N} GX_t(t) \right\|^g \right)^{\frac{1}{g}} \tag{9}$$

$$g = 2^L \tag{10}$$

$$GX(i) = X_{silverback} - (X_{silverback} * Q - X(t) * Q) * A \tag{11}$$

$$Q = 2 * r_5 - 1 \tag{12}$$

$$A = \beta * E \tag{13}$$

$$E = \int \begin{matrix} N_1, rand \geq 0.5 \\ N_{2,}, rand < 0.5 \end{matrix} \tag{14}$$

5. RESULTS AND DISCUSSION

It is critical to use a deregulated power system in order to evaluate the most current TID controller. If you're looking for a piece of electric driven powered equipment that was meticulously synthesized in that work of art, you'll need to use hydra-thermal mills. GRC and GDB are nonlinear components that are evaluated in addition to linear components. GRC depends on steam being able to circulate through the turbine and condense on the delivered contractions. Condensed steam causes water droplets to clash with turbine blades, causing them to go to pot and eventually stop working. A time-consuming procedure has the potential to create severe headaches for some people. Next, a GRC limit of 0.05% is implemented at some point throughout the setup process. GDB may be better described as the rate at which the steam valve characteristic can be replaced in the absence of torque. A 0.06% restriction is possible when the GDB is included.

5.1. Case 1: pool-co based transaction

When DISCOs in the same area share a load with any of the GENCOs in that region, the resulting transaction is known as a pool co-based transaction. The participation factor for the region is set at 0.5 for four values that are regarded as being equivalent. Figure 4(a) illustrates the deviation of frequency in area-1, Figure 4(b) illustrates the deviation of frequency in area-2, and Figure 4(c) illustrates the deviation of tie line power using various AGTO-based and grey wolf optimization (GWO-based) controllers. The AGTO-based controller outperforms the GWO-based controller when using a pool co-based transaction, as shown in Table 1.

$$APF = \begin{bmatrix} 0.5 \\ 0.5 \\ 0.5 \\ 0.5 \end{bmatrix} Disco = \begin{bmatrix} 0.1 \\ 0.1 \\ 0 \\ 0 \end{bmatrix} p.u \qquad DPM = \begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

Table 1. Comparison of difftent optimization controllersunder pool-co based transaction

S. No	% Peakovershoot (p.u)			% Peakundershoot (p.u)			Settling time (Sec)			ISE
	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	
GWO-PID	-	0.52	-	0.62	-	0.22	4.2	4.8	4.4	0.046
AGTO-PID	-	0.38	-	0.52	-	0.20	4.2	4.6	4.2	0.043
GWO-TID	-	0.36	-	0.5	-	0.18	4.0	4.4	4.0	0.041
AGTO-TID	-	0.24	-	0.44	0.02	0.16	3.8	4.2	3.8	0.038

*ISE is integral square error; Δf_1 is frequency deviation in area-1; Δf_2 is frequency deviation in area-2; and ΔP_{tie} is tie-line power deviation
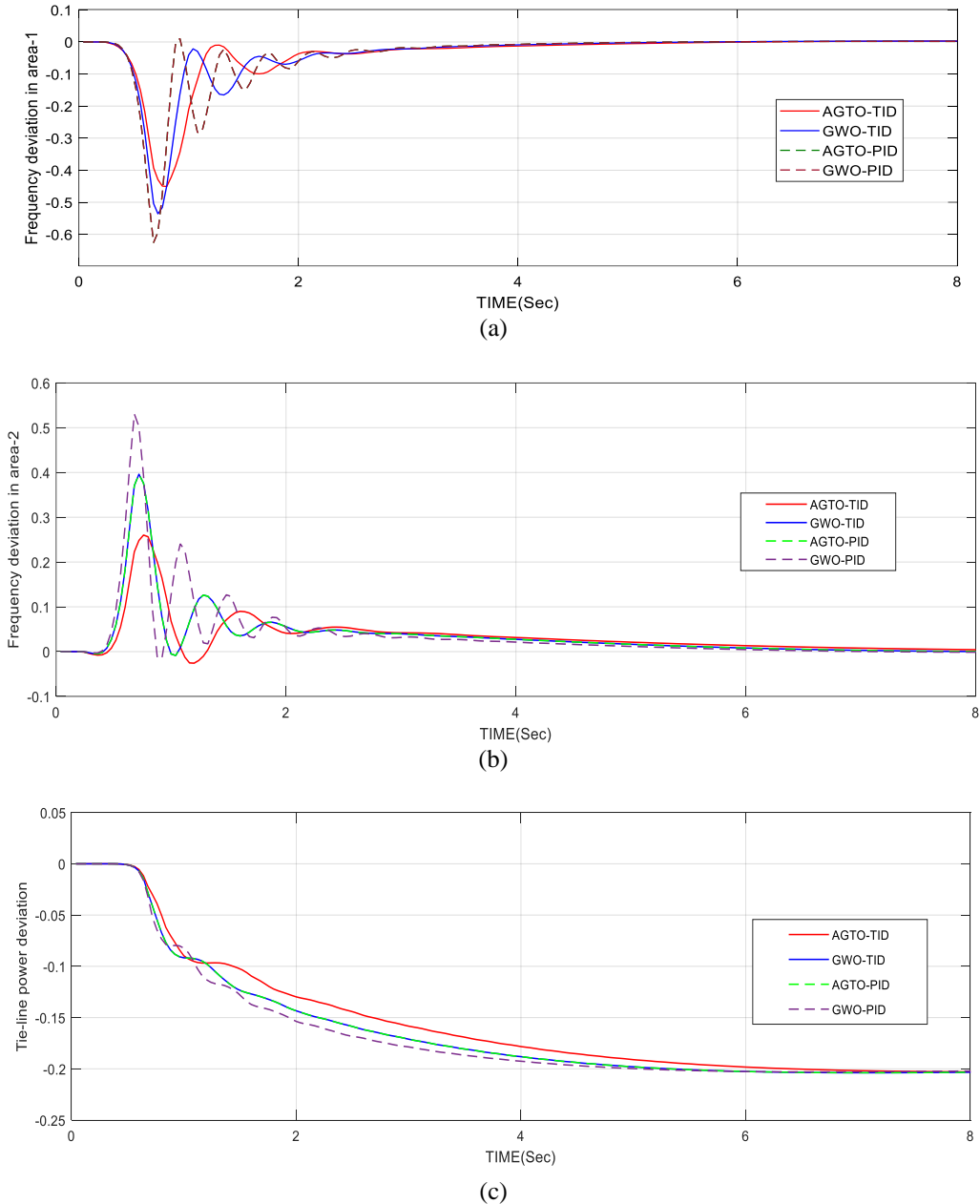
(a)

(b)

(c)

Figure 4. These figures are (a) frequency deviation in area-1, (b) frequency deviation in area-2, and
(c) tie-line power deviation under pool-co based transaction for 1% step load disturbance

5.2. Case 2: bilateral-based transaction

When DISCOs share the load with any of the GENCOs in another area, this kind of transaction is known as a bilateral based transaction. There are four values that are deemed to be uneven, and the participation factor is 0.75, 0.25, 0.5, and 0.5, respectively. Figure 5(a) illustrates the frequency variation in area-1, Figure 5(b) illustrates the frequency variation in area-2, and Figure 5(c) illustrates the tie line power variation. These three figures were created using various AGTO and GWO-based controllers. Table 2 shows that the AGTO-based controller outperforms the GWO-based controller when dealing with bilateral transactions.

$$
APF=\begin{bmatrix}0.75\\0.25\\0.5\\0.5\end{bmatrix} \quad Disco=\begin{bmatrix}0.1\\0.1\\0.1\\0.1\end{bmatrix} \quad DPM=\begin{bmatrix}0.5&0.25&0&0.3\\0.2&0.25&0&0\\0&0.25&1&0.7\\0.3&0.25&0&0\end{bmatrix}
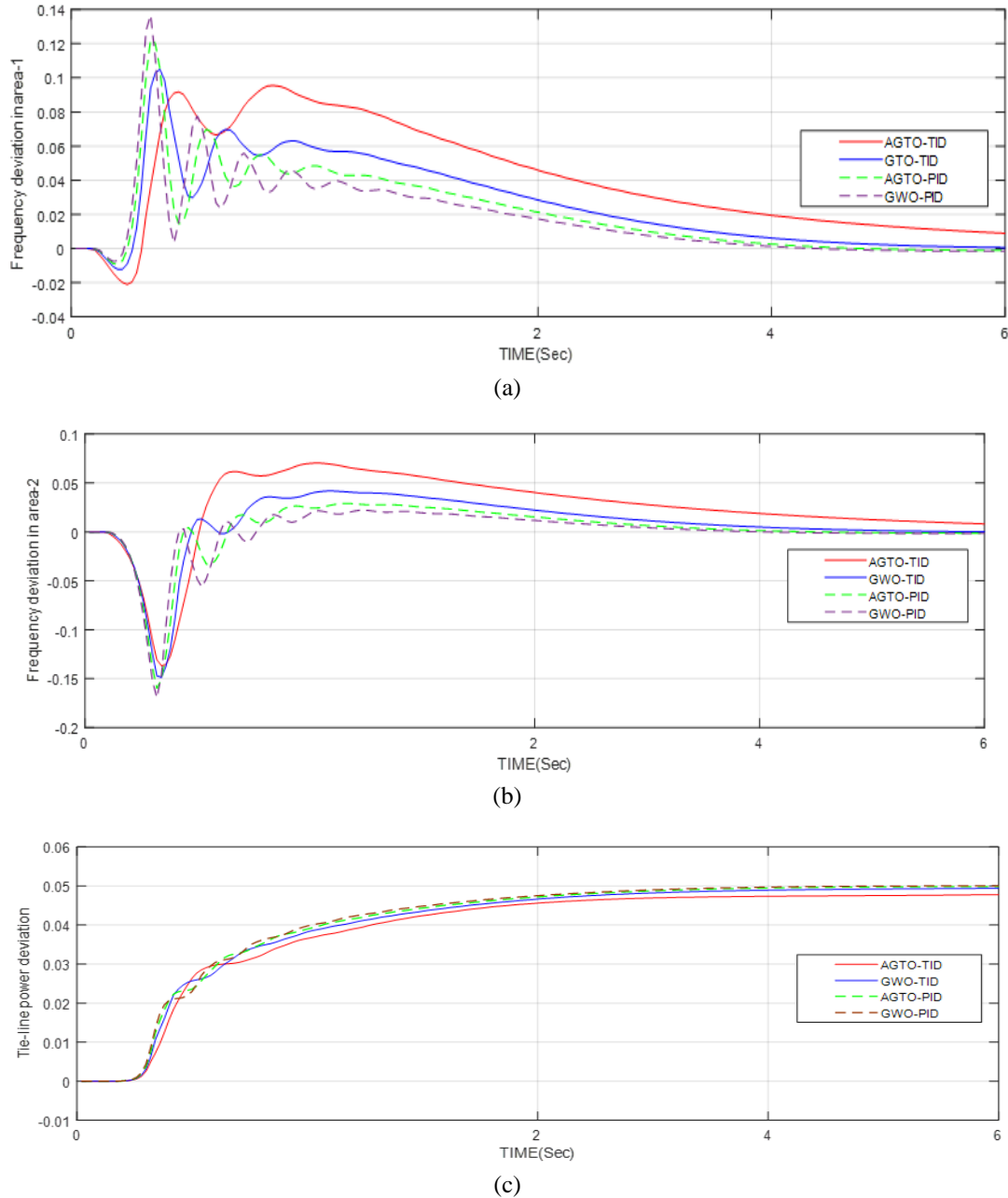$$

(a)

(b)

(c)
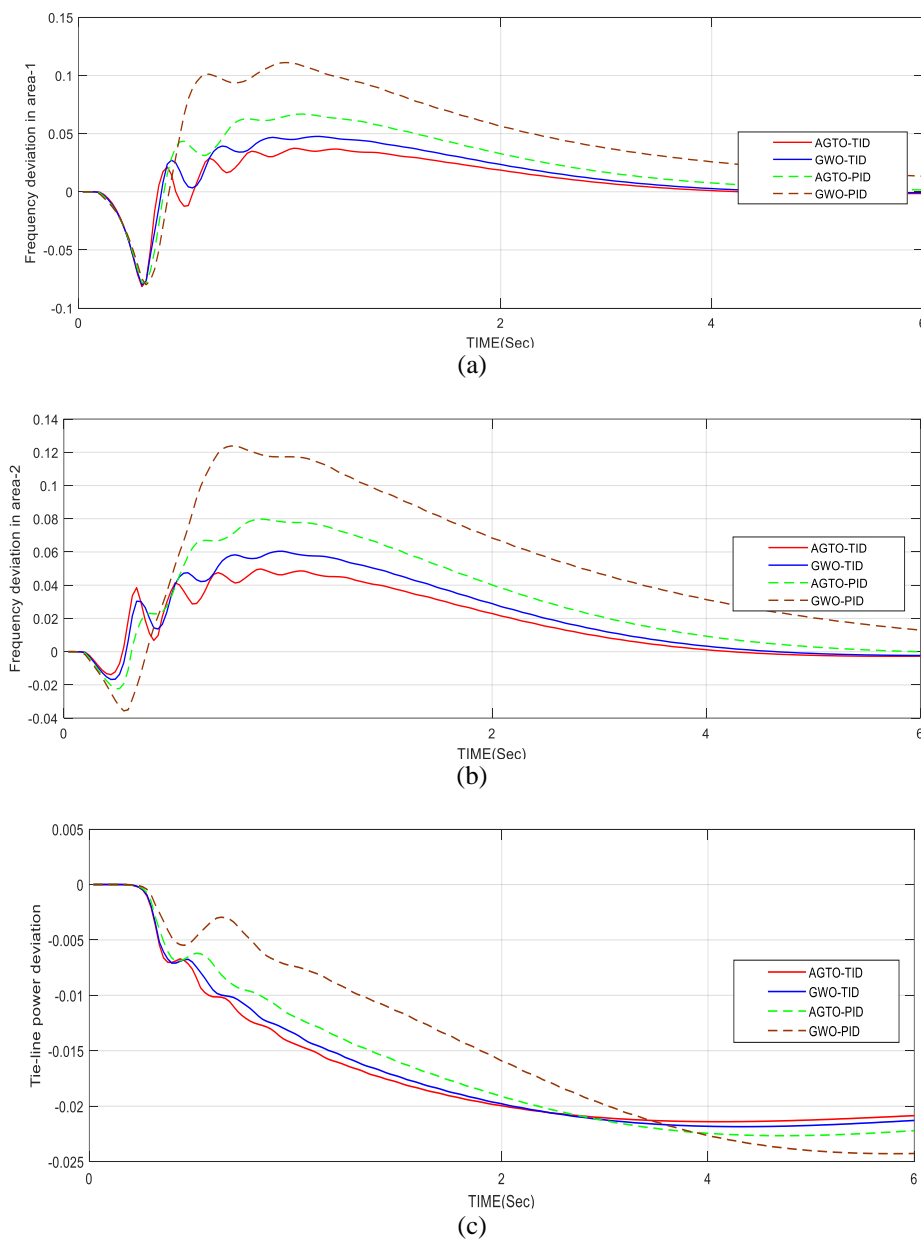
Figure 5. These figures are (a) frequency deviation in area-1, (b) frequency deviation in area-2, and
(c) tie-line power deviation under bilateral based transaction for 1% step load disturbance

Table 2. Comparison of difftent optimization controllersunder bilateral transaction

S. No	% Peakovershoot (p.u)			% Peakundershoot (p.u)			Settling time (Sec)			ISE
	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	
GWO-PID	0.13	0.02	0.052	0.01	0.17	-	4	3.2	4.2	0.028
AGTO-PID	0.12	0.03	0.05	0.01	0.16	-	4.1	3.4	3.8	0.022
GWO-TID	0.11	0.04	0.05	0.01	0.15	-	4.2	3.4	3.6	0.018
AGTO-TID	0.09	0.06	0.05	0.02	0.12	-	5	3.6	3.2	0.012

*ISE is integral square error; Δf_1 is frequency deviation in area-1; Δf_2 is frequency deviation in area-2; and ΔP_{tie} is tie-line power deviation

5.3. Case 3: contract violation

The contract is violated when the disco wants more electricity than the real value. The agreement has
been violated. There isn't a single genco that isn't benefiting from the increased electricity. Uncontracted
electricity should be provided by a genco located near the disco. If we take into consideration the scenario of a

two-area system with two discos in each area, and if we assume that each disco has a load requirement of 0.1 MW, and if now Disco1 has an additional load requirement of 0.1 MW, then we can write it down as follows:

The total local load in area 1=load of Disco1+load of Disco2
$$=(0.1+0.1)+0.1 \text{ p.u MW}$$
$$=0.3 \text{ p.u MW}$$
The total local load in area 2=load of Disco3+load of Disco4
$$=0.1+0.1 \text{ p.u MW}$$
$$=0.2 \text{ p.u MW}$$

Figure 6(a) displays the frequency deviation in area-1, Figure 6(b) displays the frequency deviation in area-2, and Figure 6(c) displays the deviation of tie line power using a variety of AGTO-based and GWO-based controllers. According to Table 3, the AGTO-based controller has better performance than the GWO-based controller when it comes to transactions involving contract violations.

Figure 6. These figures are (a) frequency deviation in area-1, (b) frequency deviation in area-2, and (c) tie-line power deviation under contract violation for 1% step load disturbance

Table 3. Comparison of difftent optimization controllersunder contract violation

S. No	% Peak overshoot (p.u)			% Peak undershoot (p.u)			Settling time (Sec)			ISE
	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	Δf_1	Δf_2	ΔP_{tie}	
GWO-PID	0.12	0.12	-	0.08	0.04	0.024	4.6	5	4.5	0.068
AGTO-PID	0.06	0.08	-	0.07	0.22	0.022	4.2	4.8	4.2	0.058
GWO-TID	0.05	0.06	-	0.07	0.018	0.02	3.8	4	3.6	0.052
AGTO-TID	0.03	0.05	-	0.06	0.01	0.018	3.6	3.8	3.4	0.04

6. CONCLUSION

It is a challenging problem to address in the power system, the network load demand, because it needs the development of a large number of controllers that are optimal. The primary responsibility of the controller is to rapidly maintain a steady frequency while also controlling the size of the voltage. In order to overcome the issues raised by LFC, a number of optimum controllers have been designed. The purpose of this study is to analyze the performance of the TID controller in a restructured situation for several different power-based transactions. The AGTO tuned controllers outperform the GWO tuned controllers in terms of faster settling time, reduced peak overshoot and undershoot under all loading scenarios. In addition, the AGTO tuned controllers outperform the GWO tuned controllers in terms of overall performance.

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