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AGC for Multi-Area Interconnected Using Computational Algorithm

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Abstract: This article outcome is a comparative analysis of Automatic Generation Control (AGC) of a multi-area interconnected hydrothermal gas system in different modes using computational algorithm controllers for the electrical and mechanical governors. Two areas have been implemented. The first area comprises a Thermal and Hydropower station, while the second area consists of a Thermal and Gas power station. The AGC of a multi-area power system is examined to increase frequency stability using improved PID controllers under 1%ΔP. The multi-technique is used to tune the gains of PID and its Sine Cosine Algorithms (SCA), Particle Swarm Optimization (PSO), Gray Wolf Optimization (GWO), and Genetic Algorithms (GA). The Implementation determines the validity of the four intelligent techniques for tuning the PID controller parameters to improve the frequency and tie-line deviation difficulties and increase the power system's stability. Finally, the SCA's comparison of dynamic performance to settling time, overshoot, and undershoot in frequency and tie-line power deviations proved to be slightly better than other algorithms with some convergence in results.

Keywords: automatic generation control, PID controller, computational algorithm, power systems.

基于计算算法的多区域互联自动发电控制

摘要：本文的成果是使用计算算法控制器对电气和机械调速器进行不同模式下多区域互连热液天然气系统的自动发电控制的比较分析。两个领域已经实施。第一个区域包括一个热力和水力发电站，而第二个区域包括一个热力和燃气发电站。使用改进的比例积分微分控制器控制器在1%ΔP下检查多区域电力系统的自动发电控制以提高频率稳定性。多技术用于调整比例积分微分控制器的增益及其正余弦算法、粒子群优化、灰狼优化和遗传算法。该实施确定了四种智能技术的有效性，用于调整比例积分微分控制器控制器参数，以改善频率和联络线偏差困难并增加电力系统的稳定性。最后，正余弦算法的动态性能与稳定时间、频率和联络线功率偏差的过冲和下冲的比较证明略好于其他算法，结果有一定的收敛性。

关键词：自动发电控制、比例积分微分控制器控制器、计算算法、电力系统.

1. Introduction

An electrical system's primary goal is to produce and distribute electrical power to various customers reliably and securely. Consumers are broadly divided into three groups based on various consuming devices: residential, industrial, and commercial. The electrical power system starts with the efficient generation of electricity and aims to provide electricity to any user, regardless of their needs. At first, the produced high voltage electrical power is transmitted at a different high voltage range through an appropriate step-up method before being stepped down at the user end according to the requirements [1], [2], [3], [4], [5].

The primary aim of using AGC is to minimize contrast in load and keep frequency (f) and voltage (V) at predetermined levels. While active (P) and reactive(Q) power have a combined effect on frequency and voltage, the frequency and voltage control problems can be solved separately by using the AGC technique [6], [7], [8], [9], [10].

The electricity network has an interconnection between them (AGC) that helps preserve the energy

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flow within the limits of these interconnection lines. Some considerations, including most economical units, coordination of unit types, and even device efficiency and network connectivity limitations, can be considered with the trend towards computer-based control systems. [11], [12], [13], [14], [15].

In recent years, different control techniques have been proposed based on conventional controllers to take the optimal value of PID gains. There are many ways and techniques, that is, (TLBO) for tuning fuzzy-PID controller for AGC of multi-area [16]. (HPSO) applied for multi-area multi-units of AGC [17]. (GA) optimization for AGC in an interconnected power system [18]. Bacterial foraging (BF) is applied to the integral controller gains with GRC to improve the AGC performance [19]. Linear matrix inequalities (LMI) based control for an AGC system [20]. BFA-based PID structured AGC [21]. BFOA-optimized fuzzy PI/PID controller for AGC of multi-area [22]. AGC by using the ANN technique [23]. (FP-PID) controller AGC [24]. Salp swarm algorithm (SSA) for tuning PID controller [25]. Multi-area AGC Scheme Using BBBC-FOPID Controller [26]. implementation of fuzzy order PID controller for AGC study [27]. PV-thermal and hydrothermal AGC by CES and FPIDF-(1+PI) controller [28]. This study compares four techniques based on the PID controller to solve the problems of frequency and tie-line deviations and maintain the stability of Gas, Hydro, and Thermal power plants.

2. Research Method

The two-area four-unit Gas-Hydro-Thermal power system is based on a "PID-controller to improve the overall stability and back the frequency and tie-line to steady-state," as shown in (Fig. 1).

2.1. Modeling System

2.1.1. Generator Model

By applying the swing equation of synchronous machine for a small deviation in speed.

$$\frac{d\Delta w}{dt} = \frac{1}{2H}\left(\Delta P_m - \Delta P_e\right)$$

By taking La place for equation

$$\Delta\Omega = \frac{1}{2H_s}\left[\Delta P_m(s) - \Delta P_e(s)\right]$$

2.1.2. Load Model

The speed – load characteristic of a composite load is approximated by:

$$\Delta P_e = \Delta P_L + D\Delta_w$$

where (ΔP_L) is the non-frequency sensitive load change, and (Δ_w) is the frequency-sensitive load change. (D) is expressed as percent change in load divided by percent change in frequency.

2.1.3. Thermal Turbine Model

"The simplest prime mover model for the steam turbine can be approximated with a single time constant (Tt), resulting in the following:

$$\frac{\Delta P_m(s)}{\Delta P_V(s)} = \frac{1}{1+T_t S}$$

2.1.4. Thermal Governor Model

By transforming the hydraulic amplifier (ΔP_g) to a steam valve position (ΔP_V)" we have the following:

$$\Delta P_V(s) = \frac{1}{1+T_g}\Delta P_g(s)$$

2.1.5. Hydro Turbine

The transfer function of the hydro turbine is:

$$\frac{\Delta P_w(s)}{\Delta P_V(s)} = \frac{1 - s\,T_w}{1 + 0.5\,s\,T_w}$$

2.1.6. Hydro Governor

The transfer function of the hydro governor is:

$$\frac{\Delta P_w(s)}{\Delta P_V(s)} = \frac{K_D S^2 + K_P S + K_I}{K_D S^2 + S\left(K_P + \frac{f}{R_2}\right) + K_I}$$

2.1.7. Gas Turbine System

The TF of the gas turbine is:

$$\frac{\Delta XE(S)}{\Delta\omega} = \frac{1}{1+sTPV}$$

2.2. Control Equation of System

Inputs to the PID-controllers are the area control error (ACE) of respective areas and controlled inputs(u_1 ,u_2) to the plant with PID-controller structure are defined as follows:

$$ACE_1 = B\Delta f_1 + \Delta P_{tie12} \quad (1)$$

$$ACE_2 = B\Delta f_2 - \Delta P_{tie12} \quad (2)$$

$$u_1 = K_{p1}ACE_1 + K_{i1}\int ACE_1 + K_{d1}\frac{d}{dt}(ACE_1) \quad (3)$$

$$u_2 = K_{p2}ACE_2 + K_{i2}\int ACE_2 + K_{d2}\frac{d}{dt}(ACE_2) \quad (4)$$

ACE is treated as the "AGC system is controlled output, used to detect any incompatibility between power generation and load demands".

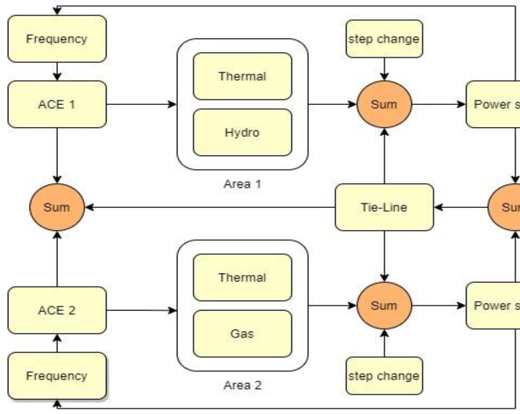


Fig. 1 Schematic diagram of (two-area four-units power system)

The selection of the objective function is carried out in an optimal control system either by "(i) taking a few points of the time response or (ii) taking the entire time response", i.e., the essential criterion. "Square of integral time error (ITSE) and ITAE have commonly used performance indices based on integral criteria" [6]. The "ITSE criterion-based controller provides large controller output for a sudden change in the reference value that is not desired from the point of view of the controller design". The fitness function for the test system can be expressed as: For test system.

$$J_1 = \int_0^{T_{Final}} t * \left[\left(\Delta f_1{}^2 + \Delta f_2{}^2 + \Delta P_{tie12}{}^2\right)\right] dt \quad (5)$$

where Tfinal is the final simulation time. The problem constraints are the parameter limit of the controller; therefore, optimal AGC problem design can be formulated as follows:

$$K_{pmin} \leq K_p \leq K_{pmax};\ K_{Imin} \leq K_I \leq K_{Imax};\ K_{Dmin} \leq K_D \leq K_{Dmax} \quad (6)$$

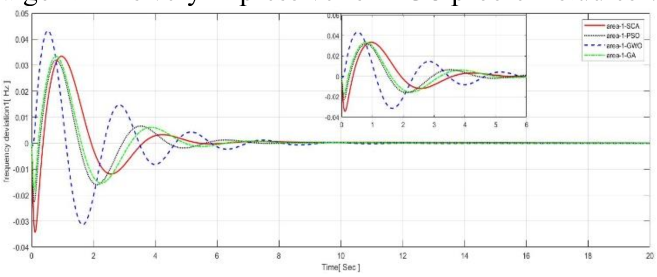
Equation (6) indicates the limited values of tune PID by the optimization techniques algorithm. A GA, GWO, SCA, PSO Algorithms are used to tune the suitable gains of the PID controller. For each area using "ITSE dependent fitness function. 1% ΔP in area-1 is considered to know the dynamic performance.

3. Optimization Controller

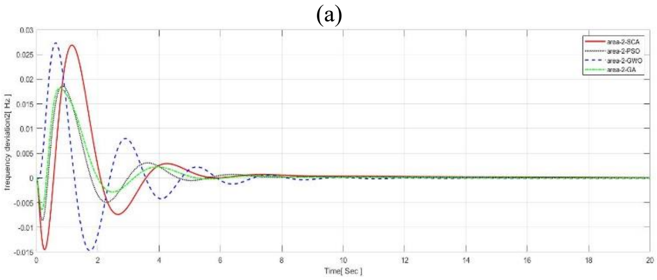
In an integrated system, a control strategy aims to achieve excellent stability and quick response. In a typical control situation, it is not possible to achieve both excellent stability and quick response simultaneously. The system with a faster response has a lower degree of stability. As a result, a good control strategy balances these two characteristics (excellent stability and quick response) to boost system performance. Kp (proportional gain), Ki (integral gain), and Kd (derivative) of a traditional PID controller must be tuned to achieve desired responses in the method. A typical PID controller's tuning mechanism can be performed best than soft computing and optimization techniques. This technique /algorithm must be used to optimize the corresponding controller parameters to increase the efficiency of higher-order complex systems. Several commonly used algorithms, such as "the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Sine Cosine algorithm (SCA), Firefly Algorithm (FA), Artificial Bee Colony (ABC), Cuckoo Search Algorithm (CSA), Gray Wolf Optimization (GWO), Ant Lion Optimizer (ALO), Moth Flame Optimizer (MFO), and others", have been proposed to tune the gains of respective controllers over the last few decades.

4. Result and Discussion

The purpose simulation aims to find the convergence between the four PID gain injection algorithm techniques used in the AGC system to know the relatively best technique in reducing and returning the deviation in the frequency and the tie line to the steady-state. The model was implemented in the Matlab environment, which consists of two areas with four units. "PID controllers with ITSE-based fitness feature are separately built for each control area with all algorithms. Therefore, as shown in Fig1, the two-area Gas-Hydro-Thermal power system with a PID controller is designed. The area-1 has a 1 % (ΔP) to investigate the dynamic stability of the power system concerned. In order to find the optimum value of PID controllers using ITSE based fitness values. The proposed SCA is to be at minimum fitness value ($\text{ITSE} = 4.356X10^{-6}$) compared to PSO ($\text{ITSE} = 4.75X10^{-6}$) and GWO ($4.5X10^{-6}$), and GA ($4.4X10^{-6}$)". The SCA-based PID controller provides relatively minimal frequency tie-line deviation and power oscillations compared to other algorithms, giving somewhat close results from others techniques. The comparative result in deviation of frequency is shown in Fig. 2 and with that disturbance, and the deviation in tie-line change is given in Fig. 3. The results of the comparison in ACE for the two areas are shown in Fig. 4. Fig. 5 shows the participation ratio between the first and second regions when carrying a load on the first 10 %. The "proposed SCA algorithm-based PID controller exceeds other intelligent controllers, suggesting clearly that the proposed SCA algorithm is very impressive for AGC problem studies".



(a)



(b)

Fig. 2 Frequency deviation of (a) area-1, (b) area-2

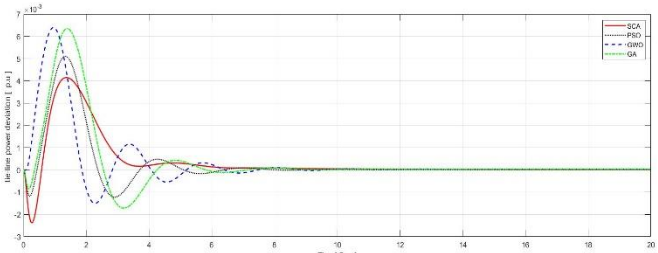
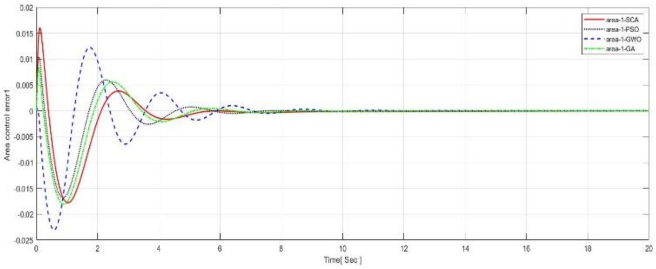
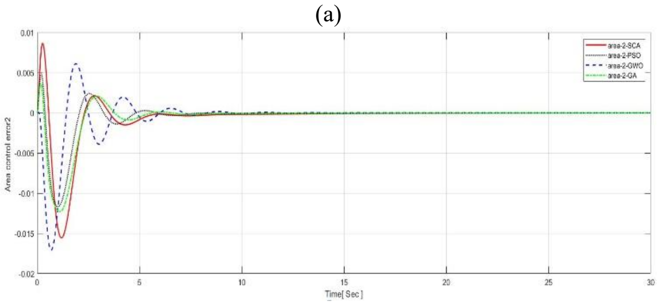


Fig. 3 Tie-line deviations by four techniques



(a)



(b)

Fig. 4 ACE deviation of (a) area-1, (b) area-2

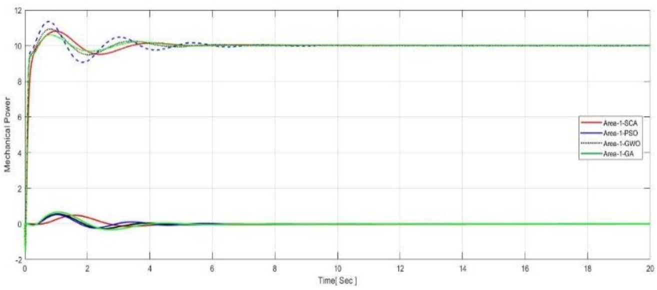


Fig. 5 Load participation between areas 1 and 2

Table 1 The most important results among three different techniques and shows the (SCA) is the best technique for the test system

Techniques	**Settling Time**			**Overshoot**		
	ΔF_1	**ΔF_2**	**ΔP_{tie}**	**ΔF_1**	**ΔF_2**	**ΔP_{tie}**
GA	6.7	6	7	0.0020	0.0029	0.0023
GWO	7.2	6.7	7.5	0.0017	0.0027	0.0019
PSO	7.04	6.8	8.4	0.0025	0.0030	0.0020
SCA	6.14	5.9	6.8	0.0012	0.0025	0.0013

Table 2 The result of different types of a fitness functions that are used

Fitness	**GA**	**GWO**	**PSO**	**SCA**
ITSE	$4.4X10^{-6}$	$4.5X10^{-6}$	$4.75X10^{-6}$	$4X10^{-6}$
ITAE	$3.14X10^{-5}$	$5.2X10^{-5}$	$4.80X10^{-5}$	$3.01X10^{-5}$
ISE	$7X10^{-6}$	$7.2X10^{-6}$	$6.8X10^{-6}$	$6.4X10^{-6}$
IAE	$17X10^{-5}$	$12X10^{-5}$	$13X10^{-5}$	$11X10^{-5}$

5. Conclusion

This study aims to compare to find efficient method. Four techniques based on the PID controller were used to test the dynamic performance by returning the deviations in frequency and the tie line between stations to the steady-state or close to zero. Two systems are commonly used in research. The power and efficiency of the proposed SCA algorithm are evaluated by two-zone and four-unit hydrothermal gas. The system's performance using the improved PID controller SCA is compared with some recently published results and PSO, GWO, and GA techniques. Finally, through simulation and comparison results with different dynamic responses, it is shown that the optimized PID controller for SCA significantly improves the dynamic performance of the system. It was found that there is a slight relative superiority of the SCA algorithm over other techniques, with the convergence of these techniques increasing the stability of the electrical system.

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