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Enhanced Chaotic Grasshopper Optimization Algorithm Based PID Controller for Automatic Voltage Regulator System

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Abstract: ***This work presents, the PID controller design for AVR system using Enhanced Chaotic Grasshopper Optimization Algorithm (ECGOA). The system response under the different settings are studied with PID controller for stable and minimum error operation. The gain of the controller revealed from traditional methods to recent optimization algorithm. The ECGOA will be implemented for AVR system with PID controller and the performance in-terms of transient response, robustness, stability and error is compared with existing optimization algorithm. The ECGOA based PID controller provides good response and examined upto ±50% of variation in several component of AVR system.***

Keywords: ***AVR System, PID Controller, Optimization algorithm, Chaotic, Grasshopper Optimization algorithm.***

I. INTRODUCTION

The prospering performance of power system engineer is to supply guarantee of steady state operation and reliable service for client. The operating voltage should be constant however it varies in real-world. All the client gadgets will be operated within the tolerable limits. The voltage decrements causes stalling in the connected loads [1].The precise standards of supply should be maintained for safety and satisfactory operation of client gadgets. The Automatic voltage controller is employed for continuing the terminal voltage at a satisfactory level. The AVR system controls the consistency of the terminal voltage by adjusting the exciter of the synchronous generator [2].The AVR has anticipated much reflection in the client to sustain the stable terminal voltage under all operating conditions. To overwhelm this problem, several customary methods were applied to adjust the controller parameters of AVR. Particularly, the PID controller is built because of its robust and easy in structure [3][32].

The PID controller was successfully implemented in process industries [4] in 1940's. It has dispute to set correct gains. The existing tuning approaches are conventional, artificial intelligence (AI) and evolutionary algorithm. The conventional tuning methods are (i) Astrom and Hagglund (AH) method (ii) Ziegler and Nichols (ZN) method proposed by John Ziegler and Nathaniel Nichols [5] in 1942. (iii) Modified Ziegler and Nichols (MZN) method (iv)Cohen Coon (CC) method proposed in 1952(v) Chien, Hrones and Reswick (CHR) method developed in 1952 which is the modified form of ZN method (vi) Tyreus and Luyben's (TL) method developed in 1997. The tuning rule of ZN, CC, CHR and TL are in described [6] [7] [30][31][33]. The controller settingsarefound from tuning rule and the parameters of tuning rule were estimated either from frequency response or time response. This approachesproduces oscillations, large overshoot and the best performances can be obtained depending upon the designer experience [8].

The human intelligence processes done by machines is called AI which is developed by John McCarthy in 1956. The AI systems are fuzzy logic and neural network. The best value acquired from AI for controller but however it require more time to train the model and affects speedy response of convergence time in real application. At present, several intelligent optimization algorithms based on evolutionary technique have been recommended to adjust the controller parameters in the AVR system like Artificial Bee Colony Algorithm(ABC) [9], Biogeography-based optimization (BBO) [10], Cuckoo Search Algorithm(CS) [8], Grasshopper Optimization Algorithm (GOA)[11], Bacterial Foraging Optimization Algorithm(BFOA)[12], Improved Kidney-Inspired Algorithm (IKA)[13], Monarch Butterfly Optimization[14], particle swarm optimization[15] [16], sine-cosine algorithm (SCA) [17], Chaotic Differential Evolution Algorithm (CDE) [3],Flower Pollination Algorithm (FPA) [18]and many more such as Ant Lion Optimizer[19], Many Optimizing Liaisons (MOL) [20], Jaya [21][22] and etc. In 2005, Karaboga reported ABC Algorithm. It is the swarm intelligence based optimization procedure to determine the optimum solution and Gozde et al[9]obtained better transient performance than PSO. Ugur guvenc et al [10] implemented the BBO Algorithm for AVR system and can attain more robustness and finest convergence characteristics than the ABC, Differential Evolutionary (DE) algorithms and PSO. The population-based

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metaheuristic optimization procedure developed by Xin-She Yang and Suash Deb in 2009. It is named as CS algorithm. Zafer BINGUL et al [8] incorporated the CS algorithm for AVR system and presented results shows the improvement in the dynamic performance and robustness as related with PSO and ABC.

Shahrzad Saremi developed the GOA in 2017 [23]. The GOA is gifted to for electrical engineering applications includes renewable microgrid[24], economic load dispatch issue [25], voltageregulator [11]. Hekimoglu et al employed GOA for AVR system and gained better performance than ZN, DE and ABC in terms of transient performance [11].Serdar Ekinci et al [13] incorporated the IKA for AVR system and had a good stability and not pretentious by the fluctuations than ABC BBO, DE, GOA PSO and many more heuristic optimization .Anbarasi et al [12] incorporated theBFOA and confirmed the better responses, stability and robustness of AVR system as relating to ABC, DE algorithms, PSO and MOL.Sambariya [14] et al presented the MBO for the system and improved transient response debated. In 2108, Baran Hekimoglu [17] presented SCA for AVR system and debated that robustness, fast and effective search to give thefinest parameters of controller as compared with ZN, ABC, BBO, DE in transient analysis

Vivekanandan et al [3] presented Chaotic DE for AVR system and discussed better performance for AVR system as compared with ZN, TL, DE.The scholar of Cambridge university X.S.Yang proposed the FPA in 2012. Sambariya et al [18] implemented the FPA for AVR system and related the result with existing optimization methods. The damping factor, eigen values, frequency oscillations were analyzed and Integral Absolute Error (IAE) performance indices taken for account.

All the mentioned works provides the robustness, improvement in transient performance in AVR system as related with existing heuristic optimization algorithm listed in Table - II. The AVR model is discussed in next section and the finest value of controller with the structure of PID controller isclaimed in section 3. The proposed optimization algorithm approaches is debated in section 4. The model setup and result are deliberated in section 5 and at last concluded with future work.

II. AVR SYSTEM MODEL

The system stability and quality of electrical power is the foremost concern factor in power system network. The AVR system has amplifier, sensor, exciter and generator. The role of AVR is to retain the magnitude of terminal voltage ΔVt(s) of a generator at its nominal value. The excitation control of generator is to improve the terminal voltage. The reference terminal voltage ΔVref(s) is set by client. The voltage sensor always senses the ΔVt(s) of generator. The difference between ΔVref(s) and ΔVt(s) is called as error. This voltage error signal is amplified and utilized to control the excitation of the generator. The model of AVR system without controller is shown in Fig.1. The transfer function of each model is given in the Table I. The range of gain and time constant of each model is also specified in Table I.

The value of gain and time constant of each model of AVR system reviewed in many research papers [9-18] and the preferred values are given in Table - I. The Eqn.1provides transfer function of AVR system and Eqn.2confer transfer function of the system after placing the value in Eqn.1. The system has two real poles and two imaginary poles. The Bode analysis, Root locus analysis and transient response are given in Table - II. The system has oscillatory response as shown in Fig. 2.

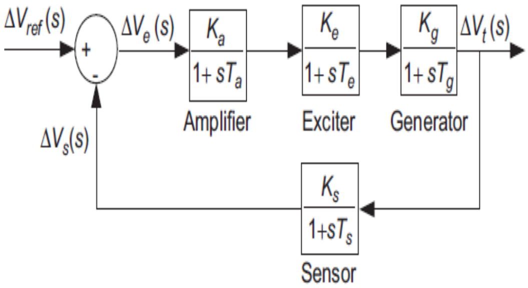

Fig. 1. Model of AVR System without controller

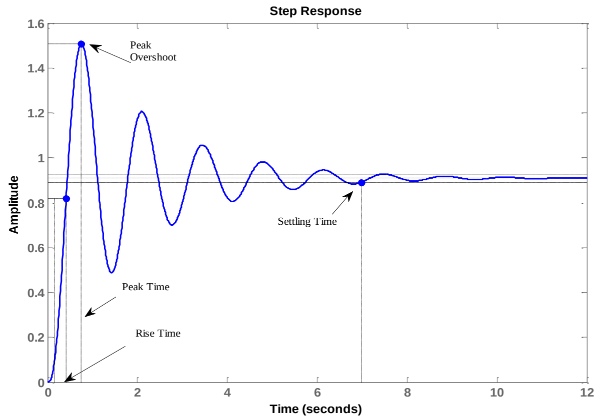

Fig. 2. Response of the AVR system without controller

$$\frac{\Delta V_t(s)}{\Delta V_{ref}(s)} = \frac{K_a K_e K_g (1+sT_s)}{(1+sT_a)(1+sT_e)(1+sT_g)(1+sT_s)+(K_a K_e K_g K_s)} \quad (1)$$

$$\frac{\Delta V_t(s)}{\Delta V_{ref}(s)} = \frac{0.1\ s+10}{0.0004s^4+0.045s^3+0.555s^2+1.51s+11} \quad (2)$$

Table - I: Transfer Function of AVR system and Values

Model	Transfer Function	Parameter Ranges	Parameter SetValue
Amplifier	$\frac{K_a}{1+sT_a}$	$10 \le K_a \le 400$ $0.02 \le T_a \le 0.1$	$K_a = 10$ $T_a = 0.1$
Exciter	$\frac{K_e}{1+sT_e}$	$1 \le K_e \le 200$ $0.4 \le T_e \le 1$	$K_e = 1$ $T_e = 0.4$
Generator	$\frac{K_g}{1+sT_g}$	$0.7 \le K_g \le 1$ $1 \le T_g \le 2$	$K_g = 1$ $T_g = 1$
Sensor	$\frac{K_s}{1+sT_s}$	$K_s = 1$ $0.01 \le T_s \le 0.06$	$K_s = 1$ $T_s = .01$

The transient response of the system are needed to improve with the support of controller and retain the terminal voltage (1.0 pu). The transient responses are rise time (t_r), settling time (t_s), peak time (t_p) and percentage of overshoot ($\%M_p$).The frequency domain analysis such as gain margin (Gm), phase margin(Pm), band width(BW), peak gain are carried out from Bode plot and root locus is used for pole location and damping analysis. All the poles of the AVR system are need to be present on left of s-plane and make the system to stable. The PID controller is incorporated with AVR system to improve the dynamic response as shown in Fig. 3.

Table – II: Analysis of AVR System

Bode Analysis	Root Locus Analysis			Transient Response Analysis
	Pole	Damping Ratio	Damping Frequency	
ωpc=5.92 rad/sec ωgc=6.22 rad/sec Gm= -2 db Pm=-5.34˚ BW=6.9454 rad/sec Peak Gain=3.8416 dB FP =4.6931 Hz	-100 -12.5 -0.52 + 4.6642i -0.52 - 4.6642i	1 1 0.11 0.11	100 12.5 4.69 4.69	tr=0.2607 sec ts=6.9865 sec tp=0.7522 sec Peak =1.5066pu Mp=65.722%

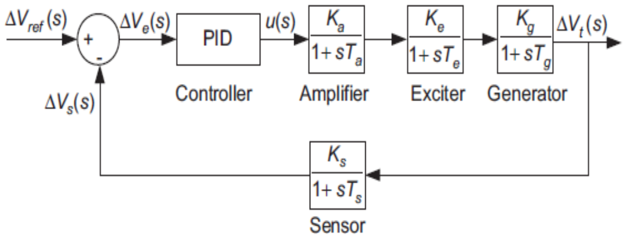

Fig. 3. AVR System with PID controller

III. PID CONTROLLER

The PID controller is most liked controller used in the industry process[4].The PID control structure is a straight dynamical framework as shown in Fig. 4 and it gets the refinement between the present structure yield and the perfect set-point as information and endeavors to limit this difference. The PID controller has three distinct mode namely proportional (P)-control, Integral (I)-Control and Derivative (D)-control. The P-controller reduces effect of rise time and never eradicates the steady-state error. The system becomes unstable for large proportional gain (K_P). The I-control eradicating the steady-state error. The integral gain (K_I) decides the system response of the gain value. The large K_I causes overshoot and low K_I will make system sluggish. The D-control increases the system stability and reduces the overshoot. The system becomes unstable for large derivative gain (K_D).

The closed loop poles moves to desired location depending upon the gain adjustment of PID controller. The effect of two real poles of AVR system can be compensated in PID controller. The correct tuning method is used to find the parameters of PID controller and the dynamic response can be improved. The trial and error method is used to find the K_P, K_I and K_D. The experience operator set the gain based on the plant behavior but cannot yield the optimum result. The conventional strategies mentioned in section 1 and ZN, TL, CC are routinely used to find the sensible parameters of PID controller. The transfer function of the PID controller specified in Eqn.(3).

The transfer function of the AVR system with PID controller is given in Eqn. (4).This approaches produces an oscillatory response with overshoot [8]. Next, the AI system incorporated for AVR system especially fuzzy PID [26] and neural network [27].

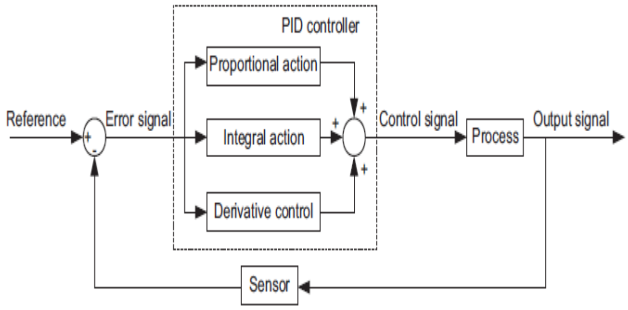

Fig. 4. PID controller structure

$$TF_{PID} = \left(K_P + \frac{K_I}{s} + K_D s\right) \quad (3)$$

$$\frac{\Delta V_t(s)}{\Delta V_{ref}(s)} = \frac{0.1K_D s^3+(0.1K_P+10K_D)s^2+(0.1K_I+10K_P)s+10K_I}{0.0004s^5+0.0454s^4+0.555s^3+(1.51+10K_D)s^2+(1+10K_P)s+10K_I} \quad (4)$$

Table – III: Optimal value of gain from heuristic optimization algorithm

Algorithm	Constrained	Optimal Value		
		K_P	K_I	K_D
ABC [9] Year:2010	$0.2 \leq K_P, K_I, K_D \leq 2$	1.6524	0.4083	0.3654
BBO [10] Year:2016	$0.2 \leq K_P, K_I, K_D \leq 2$	1.2464	0.5893	0.4596
CS [8] Year:2017	$0 \leq K_P \leq 1.5$ $0 \leq K_I, K_D \leq 1$	0.61982	0.4165	0.21269
GOA [11] Year:2018	$0.2 \leq K_P, K_I, K_D \leq 2$	1.3825	1.4608	0.5462
BFOA[12] Year:2016	$0.2 \leq K_P, K_I, K_D \leq 2$	1.087	0.8306	0.4077
IKA [13] Year:2019	$0.2 \leq K_P, K_I, K_D \leq 2$	1.0426	1.0093	0.5999
MBO[14] Year:2017	$0 \leq K_P \leq 2$ $0 \leq K_I, K_D \leq 1$	1.2454	0.7516	0.4821
SCA[17] Year:2018	$0.2 \leq K_P, K_I, K_D \leq 2$	0.9826	0.8337	0.4982
CDE[3] Year:2015	$0 \leq K_P, K_I, K_D \leq 1$	0.5716	0.4748	0.2028
FPA[18] Year:2018	$0 \leq K_P \leq 1.5$ $0 \leq K_I, K_D \leq 0.5$	1.0753	0.2675	0.2512

Now-a-days, the sensible parameter of PID controller expecting from heuristic optimization procedures like ABC, BBO, CS, GOA, BFOA, IKA, MBO, SCA, FPA and etc. The determination of lower bound and upper bound of PID controller is more crucial duty of operator and optimization problem for PID controller are defined as $K_P^{min} \leq K_P \leq K_P^{max}$, $K_I^{min} \leq K_I \leq K_I^{max}$, $K_D^{min} \leq K_D \leq K_D^{max}$. The constraint of controller is analyzed in many literatures as given in Table - III and the optimal value was found in each heuristic optimization algorithm. The parameters $K_P K_I$ and K_D are plotted as shown in Fig. 5.

Based on the literature survey K_P are constrained between the values 0 and 2 in the most of the optimized algorithm. The system performance can be improved for the best gain of K_P between the range 0.4 and 1.7 as given in Table - III. The value of K_P exploring out of this bound may not yield good response. The large search space may take more time to converge the solution and the search space is also one of the factors to converge the solution. So, the literature clearly indicates that the best K_P lies between 0.4 and 1.7 for this AVR system.

Similarly, the gain K_I and K_D bound is also analyzed in literatures and identified gain constraint is given $0.4 \le K_P \le 1.7$, $0.2 \le K_I \le 1.5$ and $0.1 \le K_D \le 0.6$.

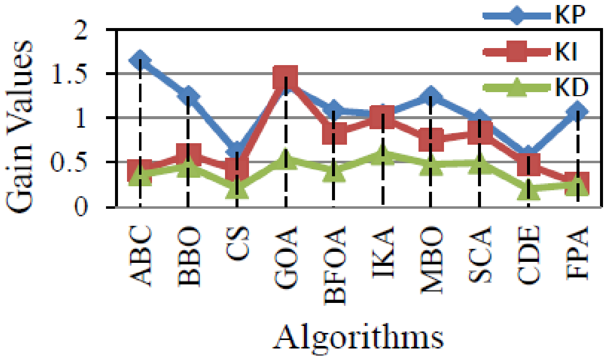

Fig. 5. Optimal value of $K_P K_I$ and K_D from heuristic optimization algorithm

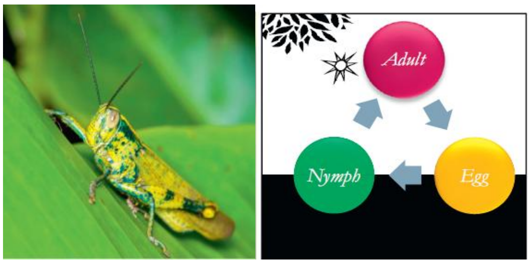

Fig. 6 (a) **Fig. 6** (b)

Fig. 6. (a) Real grasshopper (b) Life cycle of Grasshoppers

IV. GRASSHOPPER OPTIMIZATION ALGORITHM

In 2017, Saremi et al proposed the GOA [23]. Grasshoppers are pest and has three stages of are egg, nymph, adult as shown in Fig. 6. The life cycle start from fertilized egg from female grasshopper hatches into nymph. The nymph stage is called larval phase. The nymph has no wings and regenerative organs until become adulthood. The nymph has very slow movement and eats succulent plant foliages in the path. The 5-6 moults occur in nymphs to change their skeleton and structure to become an adult. The adult grasshopper have wing and swarm behavior to travel long distance for searching food source. The two tendencies of search processes in nature inspired algorithms are exploration and exploitation. The search agents are encouraged to move abruptly in exploration and move locally in exploitation. The grasshopper naturally perform the exploration and exploitation function as well as target seeking. The grasshoppers swarming behavior is mathematically presented as $X_i = S_i + G_i + A_i$. The random behavior can be written as$X_i = r_1 S_i + r_2 G_i + r_3 A_i$. The three components are social (S_i), gravitational (G_i) and target (A_i) The First component is $S_i = \sum_{j=1, j\neq i}^{N} s(d_{ij})\hat{d}_{ij}$ and the social force calculated as$s(r) = fe^{\frac{-r}{l}} - e^{-r}$. The function *s* is to divide the space between two grasshoppers into attraction region, repulsion region and comfort zone. The grasshopper are in comfort zone for *f =0.5, l=1* and the grasshopper is either at attraction region or repulsion region for other values of *f* and *l* discussed in [R4]. The second component is calculated as $G_i = -g\vec{e}_g$ and the third component is $A_i = u\vec{e}_w$. The Nymph grasshoppers have no wings and their movements are highly correlated with wind direction The components S, G, and A are substituted and given in Eqn.(5)

$$X_i = \sum_{\substack{j=1 \\ j\neq i}}^{N} s(|x_j - x_i|)\frac{x_j - x_i}{d_{ij}} - g\vec{e}_g + u\vec{e}_w \qquad (5)$$

The component G is not considered and the nymph grasshoppers land on the ground and their position should not go below a threshold. It will not utilized in the equation and optimization algorithm because it prevents the algorithm from exploring and exploiting the search space around a solution.

The Eqn (5) cannot be used directly to solve optimization problems because the grasshoppers quickly reaches the comfort zone and the swarm does not converge to a specified point. The modified mathematical equations to solve optimization problem is in Eqn.(6).

$$X_i = c\left(\sum_{\substack{j=1 \\ j\neq i}}^{N} c\frac{ub_d - lb_d}{2} s(|x_j{}^d - x_i{}^d|)\frac{x_j - x_i}{d_{ij}}\right) + T_d \qquad (6)$$

The component Ais always towards a target (T_d).The *c* is a decreasing coefficient to shrink the comfort zone, repulsion zone, and attraction zone. The outer *c* reduces the movements of grasshoppers around the target or balances exploration and exploitation of the entire swarm around the target. The component $c\frac{ub_d - lb_d}{2}$ linearly decreases and contributes to the reduction of attraction/ repulsion zone and comfort zone between grasshoppers. The component $s(|x_j - x_i|)$ indicates if a grasshopper should be repelled from (explore) or attracted to (exploitation) the target. The balancing of exploration and exploitation is achieved by the parameter *c*.

$$C(l) = C_{max} - l\frac{C_{max} - C_{min}}{L} \qquad (7)$$

The *c* is decreased proportionally as the number of iteration increases which reduces the comfort zone. The parameter *c* is calculated using Eqn.(7).The value of C_{max}=1andC_{min} =0.00001 is used for this work. The GOA optimization begins from set of random solutions. The Eqn. (6) is used to update their positions. The best target is updated in every iteration. The normalized distances among grasshoppers is[1-4] and the position is updated iteratively till it reaches to stop criterion. The final best value is called global optimum. The chaotic theory is applied for AVR system [3] [27]. The Enhanced chaotic grasshopper optimization algorithm (ECGOA)are used to find the parameter and it reduces speedily to reach the comfort zone. The different chaotic sequences [28][29] are used and the chaotic Logistic map is quite exciting to implement for AVR system [3]. The Logistic chaotic map expression is given in Eqn.(8)

$$x_{k+1} = \mu(1 - x_k) \qquad (8)$$

Whereμ=4 and the range of x is lies between 0 and 1. The normalized chaotic sequence is given in Eqn.(9)

$$N_m(l) = N_{max} - l\left(\frac{N_{max} - N_{min}}{L}\right) \text{ and}$$

$$C(l) = N(l) \times x_l \qquad (9)$$

The Eqn.(10) provides instantaneous value of chaotic sequence

$$C^{ECGOA}(l) = C^{GOA}(l) \times C(l) \qquad (10)$$

The controller gains are identified from ECGOA whose values are $K_P = 0.7224, K_I = 0.6529$ and $K_D = 0.4422$. These gains are used for implementation and the effects are discussed in the next section.

V. RESULT AND DISCUSSION

All the work are analyzed in MATLAB R2018a software environment. The code for controller algorithms are implemented in .m file and executed in Intel® core™ i3-4005U CPU of 1.7GHz,4 GB RAM Lenovo laptop. The plant response are already elaborated in section 2. The transient response of various heuristic optimization algorithm is listed in Table - IV. The percentage of overshoot is low and the rise time, peak time and settling time is high as linking with other algorithms. The overshoot of 1.59% is achieved in ECGOA. The transient analysis done at all possible circumstances and the AVR system turn into uncertainty due to the variation of time constant in every module.
Here, the maximum variation ±50% is allowed in all the component and the measured performance as given in Table - V. When the time constant of amplifier is fixed at 0.1, the rate of change (±25%, ±50 %) is applied and investigated the t_r, t_s, peak value which is decreases as Ta decreases and vice versa. The t_p is increases as T_a decreases and vice versa. The overshoot information is provided in Table - V which oscillates between the percentages of 1.63 and 9.30. Similarly the Te, Tg, Ts variation of upto ±50% is also analyzed and provided in Table - VI for quick report. At the maximum variation of time constant, the overshoot goes upto 9.39 % from normal condition. The response of AVR system with maximum overshoot for the variation of Ta is shown in Fig 7. The ECGOA is compared with least error produced existing algorithm namely ABC, CDE which has less error from zero point in positive and negative side as given Table - IV. The closed loop system have four complex pole with the damping of less than one and one real pole damping of exactly one. The system has little oscillatory response due to complex pole but produces error of 0.2434 in IAE as given Table VII. The system remains stable and examined upto ±50% of variation in any module of AVR.

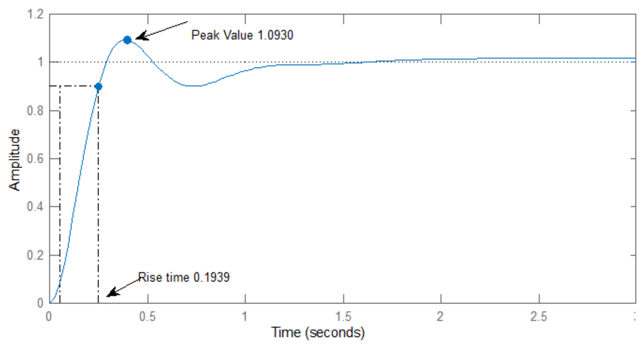

Fig.7. Response of AVR system for T_a changes to 50%

Table – IV: Transient Performance of Heuristic Optimization Algorithm

Parameters / Algorithms	Rise time	Peak time	Settling time	Peak value	% overshoot
ABC [9]	0.1557	0.3600	0.4700	1.0200	2.0
BBO[10]	0.1490	0.3170	0.7660	1.1600	16.0
GOA[11]	0.1300	0.2860	0.9710	1.2050	20.5
BFOA[12]	0.1540	0.3350	0.7590	1.1740	17.4
IKA[13]	0.1280	0.2690	0.7530	1.1500	15.0
MBO[14]	0.1440	0.3132	4.9950	1.1160	11.0
SCA[17]	0.1480	0.3040	0.7240	1.1140	11.4
CDE[3]	0.3291	0.4250	0.5200	0.9977	-0.23
FPA[18]	0.2514	0.4573	1.4480	0.9976	-0.24
ECGOA (This	0.4632	0.7623	0.9002	1.0159	1.59

Work)					

Table – V: Transient Performance of ECGOA at Different Condition

Parameters	Rate of change (%)	Rise time (sec)	Peak time (sec)	Settling time (Sec)	Peak value (pu)	% overshoot
Ta=0.1	-50	0.1589	2.7104	0.8963	1.0163	1.63
	-25	0.1621	2.6786	0.8973	1.0166	1.66
	25	0.1833	0.3658	0.8985	1.0702	7.02
	50	0.1939	0.3964	0.9004	1.0930	9.30
Te=0.4	-50	0.1084	0.2137	0.8205	1.0939	9.39
	-25	0.1408	0.2791	0.8634	1.0630	6.30
	25	0.2029	0.3838	0.9145	1.0264	2.64
	50	0.2342	2.2847	0.9171	1.0235	2.35
Tg= 1	-50	0.1002	0.2102	0.8158	1.0928	9.28
	-25	0.1353	0.2758	0.8672	1.0893	8.93
	25	0.2125	2.4339	0.9108	1.0259	2.59
	50	0.2585	2.3153	0.9032	1.0364	3.64
Ts= .01	-50	0.1782	0.3220	0.9014	1.0231	2.31
	-25	0.1754	0.3311	0.9005	1.0324	3.24
	25	0.1695	0.3166	0.8946	1.0514	5.14
	50	0.1669	0.3271	0.8912	1.0618	6.18

Table – VI: Transient Performance of ECGOA of AVR at varies condition

Parameter	Rate of change (%)	Rise time	Pea k time	Settlin g time	Peak value	% overshoot
Ta	D	D	I	D	D	D
	I	I	D	I	I	I
Te	D	D	D	D	D	D
	I	I	I	I	I	I
Tg	D	D	D	D	I	I
	I	I	I	I	D	D
Ts	D	I	D	I	D	D
	I	D	I	D	I	I

D- Decreases I – Increases

Table – VII: Comparison of ABC, CDE and ECGOA

Algorithms	Pole	Damping	Frequency (rad/seconds)	Time Constant (seconds)	IAE	Stable
ABC [9]	-0.251 -4.75 -3.76 + 8.41i -3.76 - 8.41i -101	1 1 0.408 0.408 1	0.251 4.75 9.21 9.21 101	3.98 0.211 0.266 0.266 0.009	0.3685	Yes
CDE[3]	-1.24 + 0.698i -1.24 - 0.698i -5.23 + 5.57i -5.23 - 5.57i -101	0.871 0.871 0.685 0.685 1	1.13 1.13 11.3 11.3 101.0	0.807 0.807 0.191 0.191 0.009	0.2746	Yes
ECGOA (This work)	-0.738 + 0.85i -0.738 – 0.85 -5.4 + 9.91i -5.4 - 9.91i -101	0.655 0.655 0.479 0.479 1	1.13 1.13 11.3 11.3 101.0	1.36 1.36 0.185 0.185 0.009	0.2434	Yes

VI. CONCLUSION

The design PID controller for AVR system using ECGOA under the different settings are examined with the variation of ±50% and the system is robustness, stable and minimum error as relating to traditional methods and recent optimization algorithm. The transient response especially overshoot is reduced and the other specification namely t_r, t_p, t_s may be reduce in future work.

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