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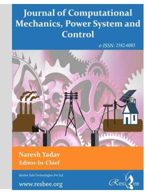

Hybrid Chaotic GWO and DA: Optimal Sizing and Positioning of D-STATCOM

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Abstract: In this work, derivation of power quality technique for distribution system via nonlinear functions is determined. Therefore the requirement for power quality improvement can be accurately enumerated. As the technique is adjustable, it requires a novel optimization technique to estimate optimal position and D-STATCOM compensation. Therefore, this work adopts a hybrid optimization model on the basis of chaotic local search techniques. The adopted hybrid chaotic GWO, as well as DA, is exploited to determine optimal sizing and positioning of STATCOM by resolving the power quality technique. In order to address both the sizing as well as localizing issue, the solution is reactive power-encoded with two bound constraints. The hybrid method integrated with two excellent approaches can enhance the inadequacy of each approach by exploiting the chaotic local search as an enhancement, and improve the exploration and exploitation of the approach concurrently therefore the sizing as well as the position of D-STATCOM can be calculated accurately. The adopted Hybrid chaotic Grey Wolf Optimization (GWO) and Dragonfly Algorithm (DA) technique evaluates its performance with the existing techniques regarding the cost analysis, Total loss, as well as ascertains the efficiency of the adopted power quality model.

Keywords: Distribution System, D-STATCOM, Optimal Sizing, Positioning, Power quality.

Nomenclature

Abbreviations	Descriptions
SC	Synchronous Compensators
RDN	Radial Distribution Networks
MCS	Monte Carlo simulation
DS	Distribution System
VDI	Voltage Deviation Index
STATCOM	Static Synchronous Compensator
DCM	Data Clustering Method
FACTS	Flexible Alternating Current Transmission System devices
MC	Matrix Converter
LHS	Latin hypercube sampling
BF	Bacteria Foraging
DN	Distribution Networks
GWO	Grey Wolf Optimization
FCS-MPC	Finite Control Set Model Predictive Control
DA	Dragonfly algorithm
CS	Cuckoo Search
D-STATCOM	distribution STATCOM
PSO	Particle Swarm Optimization

1. Introduction

In power systems, up-to-date advancement of high-power electronics presents the employ of FACTS controllers. Then, in both controlling power flow in the lines, it is shown that variable shunt compensation is extremely effectual and therefore the system voltage profiles and stability. Under the FACTS family, the STATCOM is considered a member, and that is linked in shunt with the power system. The reactive power exchanges among STATCOM and transmission lines by controlling STATCOM voltage magnitude. Therefore, the number of shunt compensation can be controlled in the power system. Additionally, a

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correctly controlled STATCOM can present enormous damping to power system oscillations to reactive power exchange. By using advanced power electronics technology, the stability margin of a conventional network can be improved [1].

Specifically, STATCOM, and FACTS devices, are exploited for technical solutions to such cases. Using power electronic-based FACTS devices one more advantage rendered evaluated with the capacitor banks as well as SC relies upon their earlier dynamic response. In addition, with these devices utilities will advantage from a cost-saving substitute for regulation of voltage as well as improved hosting ability. Though, to get better operation from these devices, the deliberate position of these controllers is critical. Finally, optimization-based techniques are exploited to deploy the FACTS devices to improve the reliability as well as loadability margins in the network [2].

To competently exploit the D-STATCOMs, their positions, as well as size, must be ascertained on basis of their technology as well as economic viewpoints. The DN probabilistic nature will affect the optimal D-STATCOMs allocation [3]. The correlation among uncertain variables creates this issue more complex. Nevertheless, the MCS technique can be exploited simply, however it is extremely time-utilizing, as well as it is unfeasible to be exploited in evolutionary-based approaches. The probabilistic evaluation techniques are used to deal with such complexity that can manage the correlation with ample accurateness and convergence speed, which are constantly significant.

To resolve the STATCOM design issue numerous optimization techniques was exploited till now. Here, the Genetic Algorithm is considered as the technique to find the optimized model of STATCM, though it consumes time-based on the system size. Few other techniques such as PSO are exploited, though the techniques lack from creating incomplete optimism. To design the STATCOM controller, the Artificial Bee Colony is exploited but it has a few disadvantages such as minimum convergence rate exploration as well as exploitation phase. The current model was the BF regarding the performance rate this method also suffers from several defects. Nevertheless, the involvement of meta-heuristic approaches in the optimal positioning of DSTATCOM is not a great deal to worry about by any analyst [4].

The main contribution of this research is to suggest a power quality design technique for the DS. Here, to estimate the optimal positioning and D-STATCOM compensation, a hybrid chaotic GWO and DA approach is proposed. The adopted hybrid chaotic GWO and DA technique evaluates its efficiency over the other conventional techniques regarding cost analysis and Total loss.

2. Literature Review

In 2020, Saeed Rezaeian-Marjani et al [1], presented a probabilistic model for optimal allocation of D-STATCOM, taking into consideration of correlation amid uncertain variables. The developed solution technique aids to enhance predictable VDI, alleviating expected active power losses, as well as minimizing D-STATCOM's expected setting up cost for mesh/ RDN. The k-means-based LHS, as well as the DCM technique, was exploited for a probabilistic estimate of DN. Additionally; the PSO model was used as the optimization tool. In 2020, Sasidharan Sreedharan et al [2], worked on the secure and safe network operation with satisfactory voltage levels has to turn out to be a demanding task for utility necessities corrective measures to be executed. By employing the FACTS the Network upgrades were considered to provide this point. Finally, using the optimal STATCOM allocation, the static loading margin enhancement to improve the power transfer ability with minimum voltage deviation was adopted. As an optimization issue, utmost loadability was devised and then given to the voltage and small-signal stability constraints. To assure the security operation in utmost loading Stability indices were proposed and integrated with the optimization issue. In 2020, Wesam Rohouma et al [3] investigated the employ of a capacitor-less D-STATCOM for compensation of power quality in up-to-date DS. The developed topology was on the basis of an MC, controlled by FCS-MPC that creates probably the employ of inductive energy storage before electrolytic capacitors which were shown to be the most failure-prone modules in a power electronic circuit. In 2017, S.M. Abd-Elazim and E.S. Ali [4], worked on a new meta-heuristic approach, the CS approach on basis of bird family life for an optimal model of STATCOM in a multi-machine environment. PV curves were designed to ascertain the optimal position of STATCOM. Using CS Algorithm, the STATCOM parameter tuning issue was transformed into an optimization issue that was resolved. In 2016, K.Karthikeyana and P.K.Dhal [5], worked on the PSO model, STATCOM device location, as well as the parameter value, which were optimized concurrently. The STATCOM performance has been experimented with via nonlinear time-domain experimentation. The outcomes were evaluated with PSO-based tuned STATCOM.

3. Problem Formulation

a. CEL

Eq. (1) states the CEL wherein TI represents time duration (hours) and EN_c represents rate TI=8760 h and EN_c =0.06$/kW h [6].

$$CEL = (\text{Total Real power loss}) * (EN_c * TI)\$ \tag{1}$$

b. Load growth

Eq. (2) states the load growth, wherein p indicates the period up of a plan to that feeder which uses load, l indicates annual growth rate, and p=5 as well as l=10% [6].

$$LOAD = LOAD \times (1+l)^p \tag{2}$$

c. Load model

Generally, load represents the variation of time which is the integration of industrial, residential, as well as commercial load. Let α represents a residential percentage, β represents a commercial percentage, and γ represents industrial load percentage at every bus. Eq. (3) and (4) indicate the practical load technique. The evaluation comprises both the winter as well as summer loads, where Q_o represents reactive power which is utilized to VO_o, P_o represent real power, as well as VO_o represents reference voltage.

$$P = P_o \left[\alpha \left(\frac{V}{V_o} \right)^{m_{al}} + \beta \left(\frac{V}{V_o} \right)^{m_{ac}} + \gamma \left(\frac{V}{V_o} \right)^{m_{ai}} \right] \tag{3}$$

$$Q = Q_o \left[\alpha \left(\frac{V}{V_o} \right)^{m_{bl}} + \beta \left(\frac{V}{V_o} \right)^{m_{bc}} + \gamma \left(\frac{V}{V_o} \right)^{m_{bi}} \right] \tag{4}$$

In [6], both the load composition as well as exponent values for all load type is represented.

d. D-STATCOM cost

Eq. (5) indicates reactive power cost persistent using DSTATCOM. A represents return's asset rate, $mDST$ represents DSTATCOM longevity (years). Where, A' =0.1, Investmentcost =50$/kVAl, $mDST$=30 years [12].

As the reactive aid is established to be a most important ancillary service as well as devices subjected to this maintenance are compensated concerning their reactive. Furthermore, for the devices, the paid cost is based on the cost investments acquired as a result of loss with DSTATCOM minimization.

$$COST^{DSTATCOM} = \text{Investment cost}^{DSTSTCOM} \times \frac{[1+A']^{mDST} * A'}{[1+A']^{mDST} - 1} \tag{5}$$

e. Voltage Stability Margin

Eq. (6) indicates the VSM [7] for all buses. Augmentation of VSM is stated by means of DSTATCOM as well as results are evaluated for enhancement of VSM at each bus. Generally, every bus's VSM is a number between 0 as well as 1. Let (DF matrix) data format, $A' = DF'(i, j2)$, $RE = DF'(i, j1)$, $SE = DFDF'(i, j)$, as well as $X = DF'(i, j3)$. In addition, j and $j1$ signifies transferring as well as receiving bus number of line, i signifies counter, as well as $j2$ $j3$ signifies branch reactance as well as resistance reactance. Here, Q indicates total reactive power loads as well as, P specifies total real power loads.

$$VSM(RE(i)) = V(SE(i))^4 - 4(P(i)x(i) - Q(I)l(i))^2 - 4\left(V(SE(i))^2 (P(i)l(i) + Q(i)x(i)) \right) \tag{6}$$

4. Optimal DSTATCOM Localizing

The sensitivity indices are exploited to recognize the optimal positioning of DSTATCOM as stated as follows [12]:

a. FVSI

Eq. (7) defines the FVSI between transmitting nodes and receiving nodes L implies line reactance, VO_i implies sending end voltage Z implies line impedance magnitude, Q_j implies reactive power of receiving end.

$$\text{FVSI} = \frac{4Z_{ij}^2 Q_j}{V_i^2 L_{ij}} \tag{7}$$

Regarding instability, a bus that possesses a maximum value of FVSI is extremely sensitive. Therefore, a bus that allows the maximum FVSI value is elected as the best bus for DSTATCOM positioning.

b. Integrity power loss sensitivity

The DSTATCOM positioning does affect both losses: reactive as well as real power losses. Hence, both losses are indicated to identify the CPLS that are stated as follows [8]:

$$\frac{\partial \text{Ploss}}{\partial Q_2} = \frac{2 * Q_{2*\hat{R}|j|}}{V_2^2} \tag{8}$$

$$\frac{\partial \text{Qloss}}{\partial Q_2} = \frac{2 * Q_{2*L|j|}}{V_2^2} \tag{9}$$

Integrated loss sensitivity regarding the reactive power

$$= \frac{\partial \hat{S}\text{loss}}{\partial Q_2} = \frac{\partial \text{aloss}}{\partial Q_2} + j\frac{\partial \text{Qloss}}{\partial Q_2} \tag{10}$$

Total loss sensitivity regarding the real power

$$= \frac{\partial \hat{S}\text{loss}}{\partial P_2} = \frac{\partial \text{aloss}}{\partial P_2} + j\frac{\partial \text{Bloss}}{\partial P_2} \tag{11}$$

Loss sensitivity matrix

$$= \begin{vmatrix} \frac{\partial \text{aloss}}{\partial P_2} & \frac{\partial \text{Bloss}}{\partial P_2} \\ \frac{\partial \text{aloss}}{\partial Q_2} & \frac{\partial \text{Bloss}}{\partial Q_2} \end{vmatrix} \tag{12}$$

The Loss sensitivity achievement is occurred by the flow of power analysis, as well as a bus that represents the peak CPLS value could be elected as the best bus to localize DSTATCOM.

c. VSI

VSI amid transmitting and receiving nodes is ascertained by the VSI enhancement [9] which is used for transmission of the network and it is stated in Eq. (13). The VSI value for the typical loading constraint should be least than "1". Nevertheless, the value attains to one for critical loading criteria. Hence, the bus with a maximum VSI value is taken into consideration as an optimal bus for positioning o DSTATCOM.

$$\text{VSI} = 4\left[Q_2 L + \frac{Q_2 \hat{R}}{L}\right]\frac{[1 - \cos 2\phi]}{2V_1^2 \sin^2(\delta_1 - \delta_2 - \phi)} \tag{13}$$

d. Voltage sensitivity index

Eq. (14) states the Voltage sensitivity Index [10] for normal operating restraints; attains least "VSEI values than unity". The bus which contributes maximum VSEI value is chosen as the finest bus for DSTATCOM positioning.

$$\text{VSEI} = \frac{4L}{V_1^2}\left(\frac{P_2^2}{Q_2} + Q_2\right) \le 1 \tag{14}$$

e. Proposed stability index

The distribution system's equivalent circuit, as well as arithmetical technique for this stability index, is stated as below; eq. (15) indicates the branch current.

$$QI_{ij} = \left[\frac{P_j + jQ_j}{V_j \angle \delta}\right] \tag{15}$$

Eq. (16) represents the bus voltage for receiving end, in Eq. (16) substitute the Eq. (15).

$$V_j \angle \delta = V_i \angle 0 - (\hat{A} + jL)I_{ij} \tag{16}$$

$$V_j\angle\delta = V_i\angle 0 - \left(\hat{A} + jL\right)\left[\frac{P_j + jQ_j}{V_j\angle\delta}\right] \tag{17}$$

$$V_j\angle\delta = V_i\angle 0 - \left(\hat{A} + jL\right)\left[\frac{P_j + jQ_j}{V_j\angle -\delta}\right] \tag{18}$$

$$V_j^2 = V_i V_j \angle -\delta - \left(\hat{A} + jL\right)\left(P_j - jQ_j\right) \tag{19}$$

$$V_j^2 = V_i V_j \cos\delta - jV_i V_j \sin\delta - \left(\hat{A} + jL\right)\left(P_j - jQ_j\right) \tag{20}$$

$$V_j^2 + \left[P_j\hat{A} + Q_j L + j\left(P_j L - Q_j\hat{A}\right)\right] = V_i V_j \cos\delta - jV_i V_j \sin\delta \tag{21}$$

In Eq. (21), divide the real and imaginary part.

$$V_j^2 + P_j\hat{A} + Q_j L = V_i V_j \cos\delta \tag{22}$$

$$P_j L - Q_j\hat{A} = -V_i V_j \sin\delta \tag{23}$$

Let $\delta \approx 0$

$$V_j^2 + P_j\hat{A} + Q_j L = V_i V_j \tag{24}$$

$$P_j L - Q_j\hat{A} = 0 \tag{25}$$

$$L = \frac{Q_j\hat{A}}{P_j} \tag{26}$$

In Eq. (22), substitute Eq. (26), Eq. (29), (30), and (31) represent the new stability index is acquired for stable bus voltage.

$$V_j^2 + P_j\hat{A} + Q_j\frac{Q_j\hat{A}}{P_j} = V_i V_j \tag{27}$$

$$V_j^2 - V_j V_i + \left(\frac{Q_j^2}{P_j} + P_j\right)\hat{A} = 0 \tag{28}$$

$$V_i^2 - 4\left(\frac{Q_j^2}{P_j} + P_j\right)\hat{A} \geq 0 \tag{29}$$

$$1 \geq \frac{4\hat{A}}{V_i^2}\left(\frac{Q_j^2}{P_j} + P_j\right) \tag{30}$$

$$PSI = \frac{4\hat{A}\hat{R}}{V_i^2}\left(\frac{Q_j^2}{V_i^2} + P_j\right) \leq 1 \tag{31}$$

Generally, the value of Psi must be lesser than the unity. If the PSI value is nearer to "0", the system is represented as extremely stable. Somewhat, if the PSI value is higher, the system turns out to be unstable. Hence, a bus with a maximum value of PSI sensitive is chosen for the best possible DSTATCOM position.

5. Objective model of the adopted approach

Eq. (32) indicates the objective model of the adopted technique. Moreover, definite restraints are stated as CEL, VSI, Demand meet, DSATCOM Cost as well as VSM. The total electrical energy is represented by the Electric demand which is utilized at a specified time. The equivalent demand must convene from the adopted load technique, if not met, subsequently include a penalty. Subsequently, VSI must be in the variation "0.96 to 1.1", if not met, subsequently include a penalty [12].

$$OB = \min\left(\begin{array}{l}\text{Demand meet, VSI Meet}\\ \text{CEL, Cost of DSTATCOM, VSM}\end{array}\right) \tag{32}$$

5.1 D-STATCOM modelling

D-STATCOM technique besides its particular static model is utilized to analyze distribution system load flow. In the connected bus, as the reactive power is aided, there has an improvement in the voltage at the buses as well as voltage profile also acquires enhanced owing to reactive power hold up as well as losses minimization.

Therefore, D-STATCOM as well affects neighboring buses' voltages. V_m indicate new voltages at candidate bus as well as $V'_{\hat{m}}$ at preceding bus. The $I'_{\hat{m}}$ current is the sum of I_{DS} as well as $I_{\hat{m}}$. Moreover, DSTATCOM inserts the current, which is called as I_{DS}. Therefore, a new voltage formulation for DSTATCOM is stated in Eq. (33).

$$V'_m\angle\theta'_m = V'_{\hat{m}}\angle\theta'_{\hat{m}} - \hat{A}\left(\hat{A}_{\hat{m}} + jL_{\hat{m}}\right)\left(I_{\hat{m}}\angle\delta\right) - \left(\hat{A}_{\hat{m}} + jL_{\hat{m}}\right)\left(BI_{DS}\angle\left(\frac{\pi}{2} + \theta'_m\right)\right) \tag{33}$$

The achievement of Eq. (34) is by dividing both real as well as imaginary segment of Eq. (33)

$$T = \frac{-A \pm \sqrt{E}}{2H} \tag{34}$$

where:

$$T = \sin\theta'_m \tag{35}$$

$$H = \left(k_1k_3 - k_2k_4\right)^2 + \left(k_1k_4 + k_2k_3\right)^2 \tag{36 a}$$

$$J = 2\left(k_1k_3 - k_2k_4\right)\cdot\left(VO'_m\right)\left(k_4\right) \tag{36 b}$$

$$K = \left(V'_m \cdot \hat{A}_{\hat{m}}\right)^2 - \left(k_1k_4 + k_2k_3\right)^2 \tag{37}$$

$$E = J^2 - 4HK \tag{38}$$

$$k_1 = \text{real}\left(V'_{\hat{m}}\angle\theta'_{\hat{m}}\right) - \text{real}\left(Z_{\hat{m}} \cdot BI_{\hat{m}}\angle\delta\right) \tag{39}$$

$$k_2 = \text{imag}\left(V'_{\hat{m}}\angle\theta'_{\hat{m}}\right) - \text{imag}\left(Z_{\hat{m}} \cdot BI_{\hat{m}}\angle\delta\right) \tag{40}$$

$$k_3 = -L_{\hat{m}} \tag{41}$$

$$k_4 = -\hat{R}_{\hat{m}} \tag{42}$$

Two roots are there T. The subsequent boundary constraints are selected to define the accurate value of the root.

$$V'_m = V_m \Rightarrow I_{DS} = 0 \; \& \; \theta'_m = \theta_m \tag{43}$$

The outcome displays the preferred root of Eq. (32), $T = \frac{-J + \sqrt{E}}{2H}$. Hence, phase angle as well as D-STATCOM current's magnitude as well as reactive power inserted to the system through D-STATCOM is stated beneath in Eq. (44) and Eq. (45), wherein * indicates the complex conjugate.

$$\angle I_{DS} = \frac{\pi}{2} + \theta'_m = \frac{\pi}{2} + \sin^{-1} T \tag{44}$$

$$|I_{DS}| = \frac{V'_m \cos\theta'_m - k_1}{-k_4 \sin\theta'_m - k_3 \cos\theta'_m} \tag{45}$$

$$jB_{DS} = \left(V'_m\angle\theta'_m\right)\cdot\left(I_{DS}\angle\left(\frac{\pi}{2} + \theta'_m\right)\right)^* \tag{46}$$

5.2Proposed Model

In this paper, both the DA and GWO approaches [11] carry out well while to resolve the high dimensional optimization issue, even though they still have a few disadvantages. The GWO approach [13] possesses high local search capability in leadership of 4 important grey wolves' social hierarchies as well as its the convergence rate is speed. The DA approach owns outstanding global search capability due to its method of being attracted towards food sources as well as distracted outward enemies, however, its convergence rate does not speed as well as it is simple to fall into local optimum. Therefore, an option technique is proposed in this paper to integrate the 2 approaches and construct full of their benefits when evading their drawbacks in the optimization procedure. Because of that the arbitrary walk of intelligence approach can't always model global search well in the optimization procedure. The principle of presenting a hybrid approach is to improve the exploitation as well as exploration of the technique, improve the searching global optimal solution performance.

Chaos owns unpredictability as well as non-periodic features that can aid to solve the issue [11]. Augmenting chaos into optimization procedure, solutions are highly enhanced.

$$\mathrm{choY}_{k+1} = \begin{cases} \dfrac{\mathrm{choY}_k}{R}; & 0 \le Y_k < R \\ \dfrac{\mathrm{choY}_k - R}{0.5 - R} & R \le Y_k < \dfrac{1}{2} \\ \dfrac{1 - \mathrm{choY}_k - R}{0.5 - R} & \dfrac{1}{2} \le Y_k < 1 - R \\ \dfrac{1 - \mathrm{choY}_k}{R} & 1 - R \le Y_k < 1 \end{cases} \tag{47}$$

Wherein choY_0 indicates primary conditions of choY_k as well as R indicates arbitrarily generate and augmenting chaotic local search can improve the local search capability of approach considerably.

6. Result and Discussion

The experimentation of the adopted approach was performed in IEEE 33 Bus system. Here, a developed approach is evaluated with conventional models regarding the total loss and Best solution.

Table 1 summarizes the obtained Total loss of both the adopted and existing techniques. The acquired loss values for all 24 hours are stated. In general, tabulated ensuing value reveals better-adapted power quality technique performance with the conventional techniques regarding minimum loss.

Table 2 summarizes optimal solutions (compensate the value of the optimal location as well as sizing) of the adopted and existing techniques. The values are cumulative for 24 hours with all 33 bus systems. The adopted model has obtained the optimal location as the best solution to the existing techniques.

7. Conclusion

In this work, an adopted hybrid chaotic GWO and DA meta-heuristic optimization algorithm was proposed and this was exploited to determine the optimal sizing as well as positioning of D-STATCOM ("reactive power compensation") to solve the power quality technique. Finally, the experimentation analysis was carried out and the adopted technique evaluated its performance with the existing techniques regarding Total loss, as well as cost analysis. Additionally, the proposed model was shown its effectuality regarding the power quality technique. Therefore, the outcomes regarding each and every measure revealed the superior performance of the adopted technique with the existing techniques.

Table 1. *Performance analysis of adopted as well as existing models regarding Total Loss*

Hours	GA	ABC	PSO	GWO	WOA	Proposed model
1	$2.4724\times e^{08}$	$2.4787\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
2	$2.4707\times e^{08}$	$2.4732\times e^{08}$	$2.4729\times e^{08}$	$2.4709\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
3	$2.4797\times e^{08}$	$2.4724\times e^{08}$	$2.4707\times e^{08}$	$2.479\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
4	$2.4787\times e^{08}$	$2.4883\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
5	$2.4774\times e^{08}$	$2.4883\times e^{08}$	$2.4728\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
6	$2.4727\times e^{08}$	$2.4702\times e^{08}$	$2.4707\times e^{08}$	$2.4709\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
7	$2.4738\times e^{08}$	$2.4737\times e^{08}$	$2.4724\times e^{08}$	$2.472\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
8	$2.4728\times e^{08}$	$2.4883\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
9	$2.4722\times e^{08}$	$2.4883\times e^{08}$	$2.4792\times e^{08}$	$2.4722\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
10	$2.4883\times e^{08}$	$2.4883\times e^{08}$	$2.4709\times e^{08}$	$2.4732\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
11	$2.4734\times e^{08}$	$2.472\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
12	$2.4744\times e^{08}$	$2.4887\times e^{08}$	$2.4727\times e^{08}$	$2.472\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
13	$2.4743\times e^{08}$	$2.4897\times e^{08}$	$2.4724\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
14	$2.4788\times e^{08}$	$2.4743\times e^{08}$	$2.4707\times e^{08}$	$2.4727\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
15	$2.4737\times e^{08}$	$2.4897\times e^{08}$	$2.4777\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
16	$2.4742\times e^{08}$	$2.47\times e^{08}$	$2.4727\times e^{08}$	$2.4723\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
17	$2.4722\times e^{08}$	$2.4883\times e^{08}$	$2.4708\times e^{08}$	$2.4777\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
18	$2.4888\times e^{08}$	$2.4883\times e^{08}$	$2.4708\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
19	$2.4798\times e^{08}$	$2.4883\times e^{08}$	$2.4727\times e^{08}$	$2.4798\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
20	$2.4788\times e^{08}$	$2.4782\times e^{08}$	$2.4707\times e^{08}$	$2.4709\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
21	$2.4748\times e^{08}$	$2.4894\times e^{08}$	$2.4783\times e^{08}$	$2.4708\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
22	$2.4792\times e^{08}$	$2.4883\times e^{08}$	$2.4707\times e^{08}$	$2.4709\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
23	$2.4749\times e^{08}$	$2.4883\times e^{08}$	$2.4794\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$
24	$2.4789\times e^{08}$	$2.4883\times e^{08}$	$2.4724\times e^{08}$	$2.4722\times e^{08}$	$2.4707\times e^{08}$	$2.4707\times e^{08}$

Table 2. *Performance analysis of the proposed and conventional models regarding the Best solution*

GA	ABC	PSO	GWO	WOA	Proposed model
28	28	44	44	44	44
7.8524	24.285	20	20	20	20
8.5284	25.498	27.825	29.829	20	20
9.5502	27.224	9.5972	2.022	20	20
24.222	20	29.848	29.829	20	20
4.2857	20	28.282	20	20	20
7.5585	8.9872	20	29.845	20	20
25.097	25.085	29.097	29.578	20	20
28.025	20	29.955	20	20	20
28.428	20	0.88407	28.449	20	20
20	20	29.892	8.9452	20	20
25.248	27.484	29.944	29.88	20	20
24.442	29.88	28.959	29.54	20	20
5.207	28.885	29.284	29.889	20	20
24.022	24.485	29.884	28.808	20	20
5.8079	28.784	4.474	20	20	20
24.488	28.489	28.794	29.208	20	20
27.458	20	29.824	2.4774	20	20
29.544	20	29.748	29.907	20	20
0.48442	20	27.809	0.28842	20	20
22.984	24.54	20	29.88	20	20
5.0578	28.949	4.8887	29.77	20	20
9.8858	20	20	29.854	20	20
24.844	20	0.85095	20	20	20
4.7727	20	29.284	29.477	20	20

Compliance with Ethical Standards

Conflicts of interest: Authors declared that they have no conflict of interest.

Human participants: The conducted research follows the ethical standards and the authors ensured that they have not conducted any studies with human participants or animals.

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