Real power loss diminution by camelopard optimization algorithm

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ABSTRACT. *In this work Camelopard optimization Algorithm (COA) has been formulated &utilized for solving the optimal reactive power problem. Activities of Camelopard & itsSocial hierarchies are imitated to formulate this algorithm. Normally males use necking, and as a weapon in assaut portion. Among mammals, the tallest living terrestrial animal and it possess the largest ruminants. It has special approach to explore the grass land in quick mode& this aspect has been utilized in the formulation of the algorithm. Efficiency of the projected Camelopard optimization Algorithm (COA) is validated by evaluating in standard IEEE 30, 57, 118, 300 bus test systems. Also by considering the voltage stability evaluation the proposed algorithm has been tested in standard IEEE 30 bus system simulated outcomes shows that genuine power loss has been reduced considerably with variables are in the limits.*

RÉSUMÉ. *Dans ce travail, l'algorithme d'optimisation Camelopard (COA) a été formulé et utilisé pour résoudre le problème optimal de la puissance réactive. Les activités de Camelopard et de ses hiérarchies sociales sont imitées pour formuler cet algorithme. Normalement, les mâles utilisent le strictard comme arme dans les assauts. Parmi les mammifères, l'animal terrestre vivant le plus haut et celui qui possède les plus grands ruminants. Il a une approche spéciale pour explorer la pelouse en mode rapide et cet aspect a été utilisé dans la formulation de l'algorithme. L'efficacité de l'algorithme d'optimisation Camelopard (COA) projeté est validée par l'évaluation des systèmes de test de bus IEEE 30, 57, 118, 300. En considérant également l'évaluation de la stabilité de la tension, l'algorithme proposé a été testé dans une simulation de système de bus IEEE 30 standard. Les résultats simulés montrent que la perte de puissance réelle a été considérablement réduite avec des variables situées dans les limites.*

KEYWORDS: *optimal reactive power, transmission loss, camelopard optimization algorithm.*

MOTS-CLÉS: *puissance réactive optimale, perte de transmission, l'algorithme d'optimisation camelopard.*

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1. Introduction

Real power loss reduction is the main aspect in this problem. Reactive power optimization plays a dominant role in power system operation & control. Reactive power and voltage control are one of the ancillary services to maintain voltage profile through injecting or absorbing reactive power in electricity market **(**Genco *et al.*, 2018). Various techniques problem (Lee *et al.*, 1984; Deeb and Shahidehpour, 1988; Bjelogrlic *et al.*, 1990; Granville 1994; Grudinin, 1998; Yan *et al.*, 2006) have been utilized but have the complexity in handling constraints. Different types of evolutionary optimization algorithms (Aparajita *et al.*, 2015; Hu *et al.*, 2010; Mahaletchumi *et al.*, 2015; Sulaiman *et al.*, 2015; Pandiarajan *et al.*, 2016; Mahaletchumi *et al.*, 2016; Rebecca *et al.*, 2016; Genco *et al.*, 2017) have been utilized in various stages to solve the problem. But evolutionary algorithms are also stuck into local optimal solution. In this work Camelopard optimization Algorithm (COA) is applied for solving reactive power optimization problem. As herds Camelopards live with related females & offspring, but bachelor herds of adult males are gathered in large aggregations in the grass lands. Social hierarchies are established by males through necking, is used as a weapon in combat bout. Special tactic of searching the grass land in fast mode has been utilized in the formulation of the algorithm. Projected Camelopard optimization Algorithm (COA) efficiency has been verified by testing it in standard IEEE 30, 57, 118,300 bus test systems. Also by considering the voltage stability evaluation the proposed algorithm has been tested in standard IEEE 30 bus system. Simulation output shows that real power loss has been reduced & control variables are within the limits.

2. Problem formulation

Modal analysis for voltage stability evaluation

Power flow equations of the steady state system is given by,

$$\begin{bmatrix}\Delta \mathrm{P}\\ \Delta \mathrm{Q}\end{bmatrix} = \begin{bmatrix}\mathrm{J_{p\theta}J_{pv}}\\ \mathrm{J_{q\theta}\ J_{QV}}\end{bmatrix}\begin{bmatrix}\Delta\theta\\ \Delta V\end{bmatrix} \tag{1}$$

Where

ΔP = bus real powerchange incrementally.

ΔQ = bus reactive Power injectionchange incrementally.

$\Delta\theta$ = bus voltage angle change incrementally.

ΔV = bus voltage Magnitudechange incrementally.

$Jp\theta$, JPV, $JQ\theta$, JQV are sub-matrixes of the System voltage stability in jacobian matrix and both P and Q get affected by this.

Presume $\Delta P = 0$, then equation (1) can be written as:

$$\Delta \mathrm{Q} = \left[\mathrm{J_{QV}} - \mathrm{J_{Q\theta}J_{P\theta^{-1}}J_{PV}}\right]\Delta \mathrm{V} = \mathrm{J_R}\Delta \mathrm{V} \tag{2}$$

$$\Delta V = J^{-1} - \Delta Q \tag{3}$$

Where

$$J_R = \left(J_{QV} - J_{Q\theta} J_{P\theta^{-1}} JPV\right) \tag{4}$$

J_R denote the reduced Jacobian matrix of the system.

2.1. Modes of voltage instability

Voltage Stability characteristics of the system have been identified through computation of the Eigen values and Eigen vectors.

$$J_R = \xi \wedge \eta \tag{5}$$

Where,

ξ denote the right eigenvector matrix of JR, ηdenote the left eigenvector matrix of JR, ∧ denote the diagonal eigenvalue matrix of JR.

$$J_{R^{-1}} = \xi \wedge^{-1} \eta \tag{6}$$

From the equations (5) and (6),

$$\Delta V = \xi \wedge^{-1} \eta \Delta Q \tag{7}$$

or

$$\Delta V = \sum_I \frac{\xi_i \eta_i}{\lambda_i} \Delta Q \tag{8}$$

ξi denote the ith column right eigenvector & η is the ith row left eigenvector of JR.

λi indicate the ith Eigen value of JR.

reactive power variation ofthe ith modalis given by,

$$\Delta Q_{mi} = K_i \xi_i \tag{9}$$

where,

$$K_i = \sum_j \xi_{ij^2} - 1 \tag{10}$$

Whereξji is the jth element of ξi

ith modal voltage variation is mathematically given by,

$$\Delta V_{mi} = [1/\lambda_i] \Delta Q_{mi} \tag{11}$$

When the value of |λi| =0 then the ith modal voltage will get collapsed.

In equation (8), when $\Delta Q = ek$ is assumed ,then ek has all its elements zero except the kth one being 1. ThenΔV can be formulated as follows,

$$\Delta V = \sum_i \frac{\eta_{1k}\ \xi_1}{\lambda_1} \tag{12}$$

η_{1k} is k th element of η_1

At bus k V –Q sensitivity is given by,

$$\frac{\partial V_K}{\partial Q_K} = \sum_i \frac{\eta_{1k}\ \xi_1}{\lambda_1} = \sum_i \frac{P_{ki}}{\lambda_1} \tag{13}$$

Minimization of actual power loss and augmentation of static voltage stability margin index (SVSM) is main key to solve optimal reactive power dispatch problem. Voltage stability evaluation has been done through modal analysis method.

2.2. Minimization of real power loss

Real power loss (Ploss) minimization is given as,

$$P_{loss} = \sum^{n}_{\substack{k=1 \\ k=(i,j)}} g_{k}(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}) \tag{14}$$

Where n is the number of transmission lines, gk is the conductance of branch k, Vi and Vj are voltage magnitude at bus i and bus j, and θij is the voltage angle difference between bus i and bus j.

2.3. Minimization of voltage deviation

Formula for reducing the voltage deviation magnitudes (VD) is derived as follows,

$$\text{Minimize VD} = \sum_{k=1}^{nl} |V_k - 1.0| \tag{15}$$

Where nl is the number of load busses and Vk is the voltage magnitude at bus k.

2.4. System constraints

Load flow equality constraints:

$$P_{Gi} - P_{Di} - V_{i\sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \cos\theta_{ij} \\ +B_{ij} & \sin\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots., nb \tag{16}$$

$$Q_{Gi} - Q_{Di} - V_{i\sum_{j=1}^{nb} V_j} \begin{bmatrix} G_{ij} & \sin\theta_{ij} \\ +B_{ij} & \cos\theta_{ij} \end{bmatrix} = 0, i = 1,2 \ldots., nb \tag{17}$$

where, nb is the number of buses, P_G and Q_G are the real and reactive power of the generator, P_D and Q_D are the real and reactive load of the generator, and G_{ij} and B_{ij} are the mutual conductance and susceptance between bus i and bus j.

$$V_{Gi}^{min} \leq V_{Gi} \leq V_{Gi}^{max}, i \in ng \tag{18}$$

$$V_{Li}^{min} \leq V_{Li} \leq V_{Li}^{max}, i \in nl \tag{19}$$

$$Q_{Ci}^{min} \leq Q_{Ci} \leq Q_{Ci}^{max}, i \in nc \tag{20}$$

$$Q_{Gi}^{min} \leq Q_{Gi} \leq Q_{Gi}^{max}, i \in ng \tag{21}$$

$$T_{i}^{min} \leq T_{i} \leq T_{i}^{max}, i \in nt \tag{22}$$

$$S_{Li}^{min} \leq S_{Li}^{max}, i \in nl \tag{23}$$

3. Camelopard optimization algorithm

As herds Camelopards live with related females & offspring, adult males are in bachelor are in the grass lands in large proposition mode. Social hierarchies are established by males through necking, is used as a weapon in combat bout. Chief distinguishing characteristics are its extremely long neck and legs, its horn-like ossicones, and its distinctive coat patterns. The sole responsibility for raising the young in the herd is by Dominant males.

Special tactic of searching the grass land in fast mode has been utilized in the formulation of the algorithm. In the problem space Camelopard is a $1XN_{var}\ array$& the array can be defined by,

$$camelopardfe = [X_1, X_2, X_3, \dots, X_{N_{var}}] \tag{24}$$

For each Camelopard the function value can be determined by,

$$\text{Value} = \text{f(Camelopard)} = \text{f}(X_1, X_2, X_3, \dots, X_{N_{var}}) \tag{25}$$

Self-regulating nature of Camelopard has been incorporated into the modeled Camelopard optimization Algorithm (COA) & written in Equation (26).

$$g_{k+1} = g_k + r_{m1}p_1(lo_{max} - n_k) + r_{m2}p_2(lf_{max} - n_k) \tag{26}$$

Exploration mentioned by g_k, exploitation byn_k, learning factors are given byr_{m1}, r_{m2} , p_1, p_2 are denoting arbitrary numbers.

Lead Camelopard will be act as an interface with abundant Camelopards as indicated in (equation (26)), there will be a comparison between each Camelopard. Movement to various locations by the Camelopard is articulated by following equation,

$$n_{k+1} = \lambda(g_k + n_k) \tag{27}$$

Fitness of each Camelopard will be computed, lq_{max} (individual Camelopard location), ls_{max} (best location of the Camelopard herd) will be found. Fitness of the current is better than (lq_{max}) location vector then that particular value will be saved. Equations (26), (27) utilized to control the movement of the Camelopard. ls_{max}, lq_{max} both play lead role in the search other & movement to other areas in search is controlled by equation (26). From the maximum vector n_k is subtracted & it will be multiplied by an arbitrary number (m_1, m_2) in the range between 0.00, 0.59 by learning parameter r_{m1}, r_{m2}.

Camelopard optimization Algorithm (COA)

Step a; Initialization

Step b; In solution space Camelopards are initiated in arbitrary mode

Step c; By using equation (26) fitness values are calculated

Step d; By using equation (27) location of the Camelopards are calculated

Step e; when $\mathbf{ls_{max}}$ updating; if yes next step otherwise goes to step b

Step f; when stop criterion is not met, then go back to step c

Step g; optimized value is output

4. Simulation results

Camelopard optimization Algorithm (COA) is tested in standard IEEE 30-bus system. In Table 1control variables are given.

Table 1. Limits

	Min Limit	Max Limit
Generator Bus value	0.95000	1.100
Load Bus value	0.95000	1.0500
Transformer-Tap value	0.9000	1.100
Shunt Reactive Compensator value	-0.1100	0.310

Power limits of the generators are listed in table 2.

Table 2. Generators power limits

Bus	Pg	Pgminimum	Pgmaximum	Qgminimum	Qgmaximum
1	96.000	49.000	200.000	0.000	10.000
2	79.000	18.000	79.000	-40.000	50.000
5	49.000	14.000	49.000	-40.000	40.000
8	21.000	11.000	31.000	-10.000	40.000
11	21.000	11.000	28.000	-6.000	24.000
13	21.000	11.000	39.000	-6.000	24.000

Control variables obtained after optimization given in table 3.COA performance presented in table 4. Comparison of active power loss is given in table 5. Fig 1 gives comparison of real power loss

Table 3. Values of control variable after optimization

Parameters	COA
Voltage at 1	1.041200
Voltage at 2	1.041340
Voltage at 5	1.020720
Voltage at 8	1.030180
Voltage at 11	1.070130
Voltage at 13	1.050420
T;4,12	0.0000
T;6,9	0.0000
T;6,10	0.9000
T;28,27	0.9000
Q;10	0.1000
Q;24	0.1000
Value of Real power loss (MW)	4.1024
Value of Voltage deviation	0.9080

Table 4. COA performance

Total number of Iterations	21
Total Time taken	4.97
Value of Real power loss (MW)	4.1024

Table 5. Evaluation of outcome

List of Techniques	Real power loss (MW)
Method SGA (Wu *et al.*, 1998)	4.9800
Method PSO (Zaho *et al.*, 2005)	4.926200
Method LP (mahadevan *et al.*, 2010)	5.98800
Method EP (mahadevan *et al.*, 2010)	4.96300
Method CGA (mahadevan *et al.*, 2010)	4.98000
Method AGA (mahadevan *et al.*, 2010)	4.92600
Method CLPSO (mahadevan *et al.*, 2010)	4.720800
Method HSA (Khazali *et al.*, 2011)	4.762400
Method BB-BC (sakthivel *et al.*, 2013)	4.69000
Method MCS (Tejaswini *et al.*, 2016)	4.8723100
Proposed COA	4.10240

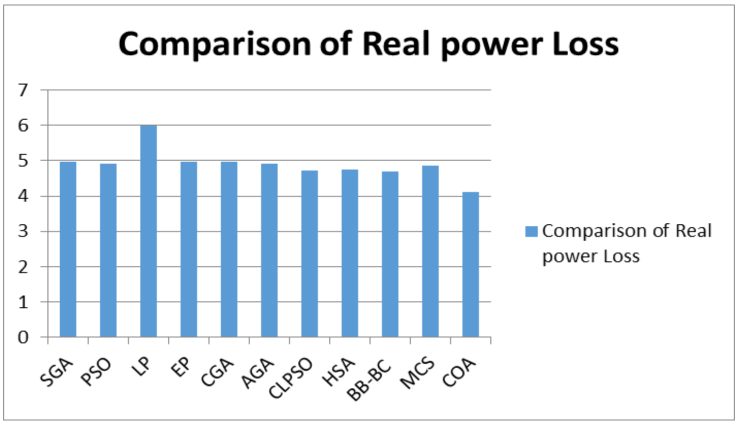

Figure 1. Comparison of real power loss

Table 6. Generator data

Generator No	Pgi minimum	Pgi maximum	Qgi minimum	Qgi maximum
1	25.000	50.000	0.000	0.000
2	15.00	90.00	-17.00	50.00
3	10.00	500.00	-10.00	60.00
4	10.00	50.00	-8.00	25.00
5	12.00	50.00	-140.00	200.00
6	10.00	360.00	-3.00	9.00
7	50.00	550.00	-50.00	155.00

Table 7. Comparison of losses

	Method CLPSO (Dai *et al.*, 2009)	Method DE (Basu *et al.*, 2016)	Method GSA (Basu *et al.*, 2016)	Method OGSA (Shaw *et al.*, 2014)	Method SOA (Dai *et al.*, 2009)	Method QODE (Basu *et al.*, 2016)	COA
PLOSS (MW)	24.5152	16.7857	23.4611	23.43	24.2654	15.8473	13.086

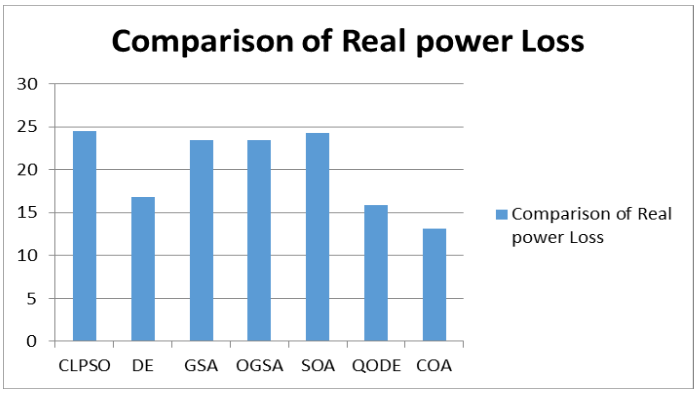

Figure 2. Comparison of loss

Secondly IEEE 57 bus system is used as test system to validate the performance of the proposed algorithm. Total active and reactive power demands in the system are 1247.89 MW and 338.04 MVAR, respectively. Generator data the system is given in

Table 6. The optimum loss comparison is presented in Table 7. Fig 2. Gives the comparaison of losses.

Table 8. Reactive power sources limits

Bus number	5	34	37	44	45	46	48
Maximum value of QC	0.000	14.000	0.000	10.000	10.000	10.000	15.000
Minimum value of QC	-40.000	0.000	-25.000	0.000	0.000	0.000	0.000
Bus number	74	79	82	83	105	107	110
Maximum value of QC	12.000	20.000	20.000	10.000	20.000	6.000	6.000
Minimum value of QC	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table 9. Evaluation of results

Active power loss – Minimum & Maximum values	Methodology - BBO (Cao *et al.*, 2014)	Methodology - ILSBBO/ strategy1 (Cao *et al.*, 2014)	Methodology ILSBBO/ Strategy2 (Cao *et al.*, 2014)	COA
Minimum value	128.770	126.980	124.780	124.872
Maximum value	132.640	137.340	132.390	129.734
Average value	130.210	130.370	129.220	126.864

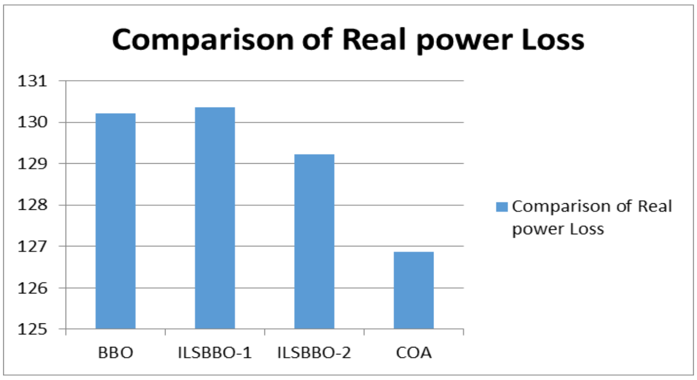

Figure 3. Comparison of actual loss

Table 9. shows the comparaison of results.

Then IEEE 118 bus system is used as test system to validate the performance of the proposed algorithm. Table 8 shows limit values.

Finally IEEE 300 bus system is used as test system and Table10 shows the comparaison of real power loss.

With Considering Voltage Stability Evaluation Criterion in IEEE 30 bus system projected algorithm has been verified. Table 11 shows the optimal control variables.

Table 10. Comparison of real power loss

Parameter	Method EGA (Reddy *et al.*, 2014)	Method EEA (Reddy *et al.*, 2014)	COA
PLOSS (MW)	646.2998	650.6027	629.1898

Table 11. COA-ORPD based control variables

Parameter	value
voltage at 1	1.03142
voltage at 2	1.03418
voltage at 5	1.03192
voltage at 8	1.02198
voltage at 11	1.00032
voltage at 13	1.02079
value of T11	1.00114
value of T12	1.00021
value of T15	1.0021
value of T36	1.0001
value of Qc10	3.00
value of Qc12	3.00
value of Qc15	2.00
value of Qc17	0.00
value of Qc20	2.00
value of Qc23	3.00
value of Qc24	3.00
value of Qc29	2.00
Real power loss in MW	4.1248
Value of SVSM	0.2382

Static voltage stability index rises from 0.2382 to 0.2396.

In table 12 optimal (control variables) are given.

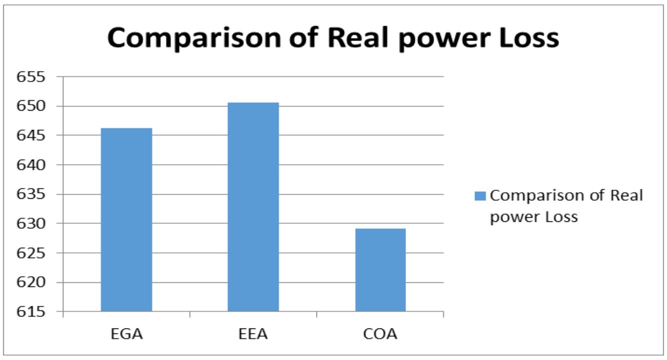

Figure 4. Comparison of active power loss

Table 12. Value of COA -voltage stability control reactive power dispatch optimal control variables

Parameter	values
voltage at 1	1.03279
voltage at 2	1.03184
voltage at 5	1.03465
voltage at 8	1.03254
voltage at 11	1.00114
voltage at 13	1.03012
value of T11	0.09001
value of T12	0.09000
value of T15	0.09000
value of T36	0.09000
value of Qc10	3.00
value of Qc12	3.00
value of Qc15	2.00
value of Qc17	3.00
value of Qc20	0.00
value of Qc23	2.00
value of Qc24	2.00
value of Qc29	3.00
Real power loss in MW	4.9972
Value of SVSM	0.2396

In Table 13 Eigen values are given.

Table 13. Values of settings

Area of; Contingency	ORPD Setting values	VSCRPD Setting values
28-27	0.14100	0.14240
4-12	0.16380	0.16480
1-3	0.17610	0.17720
2-4	0.20220	0.20410

In table 14 values for limit violation checking has been given with upper & lower limits.

Table 14. Limits of violation

Parameter	Types of Limits values		Values of; ORPD	Values of; VSCRPD
	Lower level	Upper level		
At Q1	-20.00	151.0	1.3421	-1.3261
At Q2	-20.00	61.00	8.9902	9.8230
At Q5	-15.00	49.920	25.926	26.000
At Q8	-10.00	63.520	38.8201	40.800
At Q11	-15.00	42.0	2.9309	5.001
At Q13	-15.00	48.0	8.1020	6.030
At V3	0.950	1.050	1.0371	1.0390
At V4	0.950	1.050	1.0304	1.0321
At V6	0.950	1.050	1.0287	1.0290
At V7	0.950	1.050	1.0100	1.0154
At V9	0.950	1.050	1.0466	1.0416
At V10	0.950	1.050	1.0480	1.0492
At V12	0.950	1.050	1.0402	1.0460
At V14	0.950	1.050	1.0476	1.0442
At V15	0.950	1.050	1.0458	1.0412
At V16	0.950	1.050	1.0420	1.0400
At V17	0.950	1.050	1.0384	1.0392
At V18	0.950	1.050	1.0396	1.0402
At V19	0.950	1.050	1.0382	1.0396
At V20	0.950	1.050	1.0110	1.0196
At V21	0.950	1.050	1.0434	1.0248
At V22	0.950	1.050	1.0446	1.0392
At V23	0.950	1.050	1.0476	1.0370
At V24	0.950	1.050	1.0488	1.0374
At V25	0.950	1.050	1.0140	1.0198
At V26	0.950	1.050	1.0490	1.0426
At V27	0.950	1.050	1.0478	1.0458
At V28	0.950	1.050	1.0246	1.0280
At V29	0.950	1.050	1.0432	1.0412
At V30	0.950	1.050	1.0414	1.0390

In table 15 over all comparison of real power loss has been given. It indicates that proposed algorithm efficiently reduced power loss. Fig 5. Gives Comparison of real power loss

Table 15. Comparison of losses

Technique	Loss value in MW
Method; Evolutionary programming (Wu *et al.*, 1995)	5.01590
Method; Genetic algorithm (Durairaj *et al.*, 2006)	4.6650
Method; Real coded GA with Lindex as SVSM (Devaraj *et al.*, 2007)	4.5680
Method; Real coded genetic algorithm (Aruna *et al.*, 2010)	4.50150
Proposed COA	4.1248

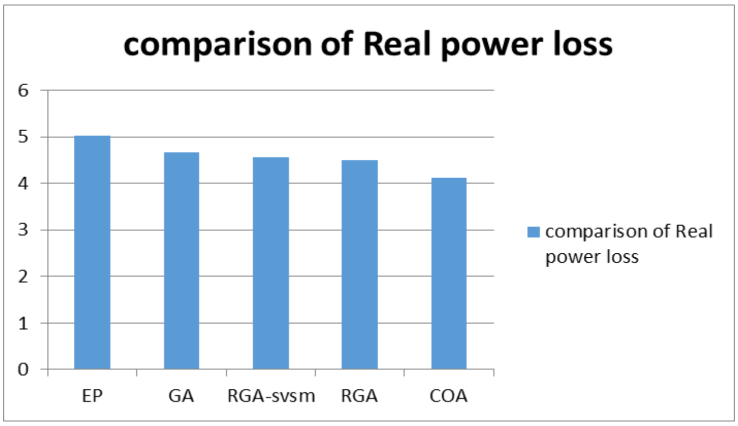

Figure 5. Comparison of real power loss

5. Conclusion

In this work Camelopard optimization Algorithm (COA) efficiently solved the power problem. Mathematical modeling efficiently improved the search of the optimal solution. Both the exploration & exploitation has been comparatively increased in the proposed technique. Camelopard optimization Algorithm (COA) has performed well when evaluated in standard IEEE 30, 57, 118, 300 bus test systems. Also by considering the voltage stability evaluation the proposed algorithm has been successfully tested in standard IEEE 30 bus system. True power loss reduced considerably when compared to another standard algorithm.

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