UDC 519.6 EDN: FEQTXE

OPPOSITION BASED RUSSIAN ICE HOCKEY OPTIMIZATION ALGORITHM FOR POWER LOSS LESSENING AND STABILITY AMPLIFICATION

L. Kanagasabai gklenin@gmail.com

Prasad V. Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada, India

Abstract

In this paper, Opposition based Russian ice hockey optimization algorithm (ORIHO) is applied for solving the power loss lessening problem. Russian ice hockey optimization algorithm is stimulated by ice hockey playing methods which emphases on hockey puck fleeting and competitor locating. Ice hockey is a connexion midwinter squad game played on ice skateboards, customarily on a hoarfrost slithering arena with streaks and colorations explicit to the game. The competitor or player location signifies the contender solution. In the interim, the hockey puck location is the elucidation vector that will control the locus of the subsequent competitor. Moreover, players characterize a set of elucidation. Chaotic sequences are integrated into ORIHO algorithm. Tinkerbell chaotic map engendering standards are implemented. Opposition based Learning ORIHO algorithm utilize Laplace distribution to enhance the exploration skill. Then examining the prospect to widen the exploration, a new method endorses stimulating capricious statistics used in formation stage regulator factor in ORIHO algorithm. Proposed Opposition based ORIHO algorithm is corroborated in IEEE 30, 57, 118, 300 and 354 bus test systems. True power loss lessening, power divergence curtailing, and power constancy augmentation has been achieved

Keywords

Optimal, reactive, transmission loss, Russian ice hockey, chaotic, opposition based

Received 11.12.2021
Accepted 03.06.2022

Introduction. Loss decreasing problem in system is intended as one of the incredible environments for innocuous and monetary operation. It is supreme by suitable association of the association contraption used to manage up the power flow with the goal of diminishing the true power losses and progress the voltage outline of the structure. Zhu *et al* [1] solved the problem by modified interior point method. Quintana *et al* [2] solved by successive quadratic programming.

Jan *et al* [3] used Newton — Raphson. Terra *et al* [4] did Security-constrained mode. Grudinin N. [5] used successive quadratic programming. Ebeed *et al* [6] used marine predators algorithm. Sahli *et al* [7] used hybrid algorithm. Davoodi *et al* [8] used semidefinite method. Bingane *et al* [9] applied tight-and-cheap conic relaxation approach. Sahli *et al* [10] applied hybridized PSO-Tabu. Mouassa *et al* [11] applied ant lion algorithm for solving the problem. Mandal *et al* [12] solved by using quasi-oppositional. Khazali *et al* [13] solved the problem by harmony search procedure. Tran *et al* [14] solved by fractal search procedure. Polprasert *et al* [15] solved the problem by using enhanced pseudo-gradient method. Duong *et al* [16] solved the problem by an operative metaheuristic procedure. Raghuwanshi *et al* [17] utilized bagging based ELM. Yu *et al* [18] applied dual-weighted kernel ELM. Lv *et al* [19] used kernel ELM. From Illinois Center[1] for a Smarter Electric Grid (ICSEG) IEEE 30 bus system data obtained. Dai *et al* [20] used seeker optimization procedure for solving the problem. Subbaraj *et al* [21] used self-adaptive real coded genetic procedure to solve the problem. Pandya *et al* [22] applied particle swarm optimization to solve the problem. Hussain *et al* [23] applied amended particle swarm optimization to solve the problem. Vishnu *et al* [24] applied an enhanced particle swarm optimization to solve the problem. Omelchenko I.N. *et al* did development of a design algorithm for the logistics [25], did the work on organization of logistic systems of scientific productions [26], solved the problems and organizational and technical solutions [27]. Khunkitti *et al* [28] used slime mould algorithm. Diab *et al* [29] used optimization techniques. Surender [30] and Reddy [31] solved the problem by faster and cuckoo search algorithms. Sridhar *et al* [32] used ALO method. Suja [33] used moth flame optimization procedure. Darvish Falehi [34] applied grasshopper optimization algorithm. Sharma *et al* [35] used hybrid ABC-PSO. Bentouati *et al* [36] applied improved moth-swarm algorithm. Menon *et al* [37] applied OS-DPLL. Saxena *et al* [38] used STATCOM. Kazmi *et al* [39] worked on loop configuration. Sambaiah *et al* [40] worked in EDN. Zaidan *et al* [41] worked in var comp. optimal location. Lakshmi Priya *et al* [42] used GWO-BSA. Ahmadnia *et al* [43] worked in ESR. Ashpazi *et al* [44] worked in thyristor-controlled phase shifting. Juneja [45] used a fuzzy-controlled differential evolution to solve the problem. Kien *et al* [46] used discrete values of capacitors and tap changers. Mouassa *et al* [47] applied ant lion optimization algorithm. Tudose *et al* [48] applied improved salp swarm algorithm. Karthik *et al* [49] applied levy interior search algorithm. Mei *et al* [50]

[1] Illinois Center for a Smarter Electric Grid (ICSEG).
Available at: https://icseg.iti.illinois.edu (accessed: 06.08.2024).

applied moth-flame optimization technique. Nuaekaew *et al* [51] applied grey wolf optimizer. Khazali *et al* [52] applied harmony search algorithm. Chen *et al* [53] applied enhanced PSO algorithm. IEEE 57-bus test system data obtained[2]. From Power systems test case archive[3] (University of Washington) data obtained. IEEE 118 bus test system data obtained[4]. Zou *et al* [54] applied chaos cultural sine cosine algorithm. Inoue [55] used dynamical systems chaos. Dinkar *et al* [56] used opposition based Laplacian ant lion optimizer.

In this paper, opposition based Russian ice hockey optimization algorithm (ORIHO) is applied for solving the power loss lessening problem. Russian ice hockey optimization algorithm is stimulated by ice hockey playing methods which emphases on hockey puck fleeting and competitor locating. Chaotic sequences are integrated to magnify the exploration and exploitation. Opposition based ORIHO algorithm utilize Laplace distribution to enhance the exploration skill. Special features of the Russian ice hockey team:

–Russia is one of the most successful national ice hockey teams in the world and a member of the so-called “Big Six, the unofficial group of the six strongest men’s ice hockey nations, along with Canada, the Czech Republic, Finland, Sweden and the United States. So, the strategy used by the esteemed Russian ice hockey team has been imitated to design the algorithm;

–Russian ice hockey team won nearly every world championship and Olympic tournament between 1954 and 1991 and never failed to medal in any International Ice Hockey Federation (IIHF) tournament they competed.

Proposed ORIHO algorithm is corroborated in IEEE 30, 57, 118, 300 and 354 bus test systems. True power loss lessening, power divergence curtailing, and power constancy augmentation has been achieved.

Problem formulation. Power loss minimization [50–53] is defined by $\min \tilde{F}\left(\overline{d}, \overline{e}\right)$, where min is minimization of power loss. Subject to the constraints $A\left(\overline{d}, \overline{e}\right) = 0$; $B\left(\overline{d}, \overline{e}\right) = 0$, *d, e* are control and dependent variables,

$$d = \left[VLG_1, \ldots, VLG_{Ng};\ QC_1, \ldots, QC_{Nc};\ T_1, \ldots, T_{NT} \right];$$

[2] The IEEE 57 bus test system.
Available at: http://www.ee.washington.edu/research/pstca/pf57/pg_tca57bus.htm (accessed: 06.08.2024).

[3] Power systems test case archive, University of Washington.
Available at: http://www.ee.washington.edu/research/pstca/ (accessed: 06.08.2024).

[4] The IEEE 118 bus test system.
Available at: http://www.ee.washington.edu/research/pstca/pf118/pg_tca118bus.htm (accessed: 06.08.2024).

$$e = \left[PG_{slack};\ VL_1, \ldots, VL_{NLoad};\ QG_1, \ldots, QG_{Ng};\ SL_1, \ldots, SL_{NT} \right].$$

Here QC is reactive power compensators; T is tap setting of transformers; PG_{slack} is slack generator; VL_g is level of the voltage; QG is generation unit's reactive power; SL is apparent power.

The fitness function (f_1, f_2, f_3) is designed for power loss (MW) lessening, voltage deviancy, voltage constancy index (L-index) is defined by:

$$f_1 = P_{\min} = \min \left[\sum_{m}^{NTL} G_m \left[V_i^2 + V_j^2 - 2V_iV_j \cos \varnothing_{ij} \right] \right];$$

$$f_2 = \min \left[\sum_{i=1}^{N_{LB}} \left| VL_k - VL_k^{desired} \right|^2 + \sum_{i=1}^{Ng} \left| QG_K - QK_G^{\lim} \right|^2 \right];$$

$$f_3 = \min L_{\max},$$

where NTL is number of transmission line; VL_k is load voltage in k-th load bus; $VL_k^{desired}$ is voltage desired at the k-th load bus; QG_K is reactive power generated at k-th load bus generators; $QK_G^{\lim}$ is reactive power limitation; N_{LB}, Ng are number load and generating units; $L_{\max} = \max \left[L_j \right]$, $j = 1, \ldots, N_{LB}$,

$$L_j = 1 - \sum_{i=1}^{NPV} f_{ji} \frac{V_i}{V_j},\ f_{ji} = -\left[Y_1 \right]^1 \left[Y_2 \right];\ L_{\max} = \max \left[1 - \left[Y_1 \right]^{-1} \left[Y_2 \right] \frac{V_i}{V_j} \right].$$

Parity constraints:

$$0 = PG_i - PD_i - V_i \sum_{j \in NB} V_j \left[G_{ij} \cos \left[\varnothing_i - \varnothing_j \right] + B_{ij} \sin \left[\varnothing_i - \varnothing_j \right] \right];$$

$$0 = QG_i - QD_i - V_i \sum_{j \in NB} V_j \left[G_{ij} \sin \left[\varnothing_i - \varnothing_j \right] + B_{ij} \cos \left[\varnothing_i - \varnothing_j \right] \right].$$

Disparity constraints:

$$PG_{slack}^{\min} \le PG_{slack} \le PG_{slack}^{\max};\ QG_i^{\min} \le QG_i \le QG_i^{\max},\ i \in Ng,$$

$$VL_i^{\min} \le VL_i \le VL_i^{\max},\quad i \in NL,\quad T_i^{\min} \le T_i \le T_i^{\max},\quad i \in NT,$$

$$QC^{\min} \le QC \le QC^{\max},\quad i \in NC,\ \left| SL_i \right| \le SL_i^{\max},\quad i \in NTL,$$

$$VG_i^{\min} \le VG_i \le VG_i^{\max},\quad i \in Ng.$$

Multi objective fitness function:

$$MOF = f_1 + r_i f_2 + u f_3 =$$

$$= f_1 + \left[\sum_{i=1}^{NL} x_v \left[VL_i - VL_i^{\min} \right]^2 + \sum_{i=1}^{Ng} r_g \left[QG_i - QG_i^{\min} \right]^2 \right] + r_f f_3,$$

where u is dependent variables;

$$VL_i^{\min} = \begin{cases} VL_i^{\max}, VL_i > VL_i^{\max}; \\ VL_i^{\min}, VL_i < VL_i^{\min}, \end{cases} \quad QG_i^{\min} = \begin{cases} QG_i^{\max}, QG_i > QG_i^{\max}; \\ QG_i^{\min}, QG_i < QG_i^{\min}. \end{cases}$$

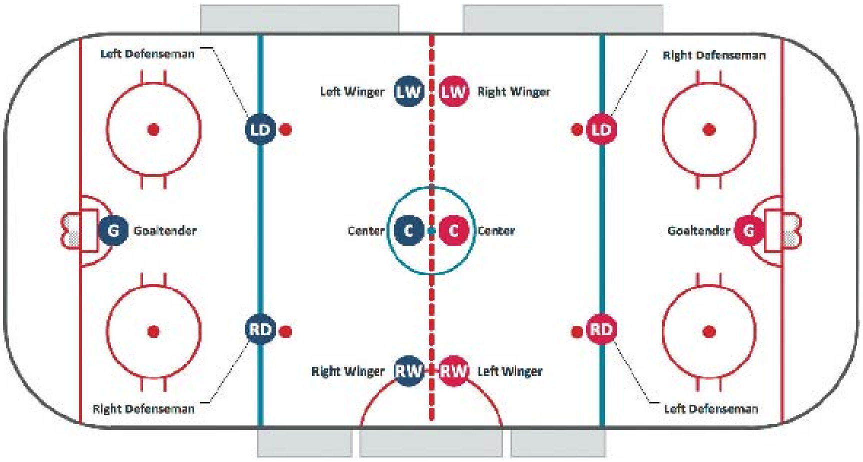
ORIHO algorithm. ORIHO algorithm is stimulated by ice hockey playing methods which emphases on hockey puck fleeting and competitor locating. Ice hockey is a connexion midwinter squad game played on ice skateboards, customarily on a hoarfrost slithering arena with streaks and colorations explicit to the game. It is one of the dissolute squad games using hockey puck. In Russian ice hockey, two opposite squads utilize ice hockey batons to regulate progress and sprout the hockey puck into the other squad's goalmouth. Every goal is a value of single point. The squad which notches the maximum goals is professed as the victor. In an official sport, every squad possess players in the playing arena including goaltender. The preliminary aim of the approach is to regulate the play by preserving the hockey puck possession. Players in both squads will try to possess the hockey puck continuously. Once the hockey puck ball is nearby to the rival's goal post, the competitor will strike the hockey puck into goal post. The competitor or player location signifies the contender solution. In the interim, the hockey puck location is the elucidation vector that will control the locus of the subsequent competitor. Moreover, players characterize a set of elucidation. Figure shows the Russian ice hockey playing environment.

At the preliminary phase, the competitor location is arbitrarily formed:

$$H_S = \begin{bmatrix} H_{1,1} & \dots & H_{1,n\times m} \\ \vdots & \ddots & \vdots \\ H_{S,1} & \dots & H_{S,n\times m} \end{bmatrix},$$

where H is the players of the Russian ice hockey; S is specifying the population size; n, m are dimensions. Hockey puck location is defined as

$$HP_S = \begin{bmatrix} HP_{1,1} & \dots & HP_{1,n\times m} \\ \vdots & \ddots & \vdots \\ HP_{S,1} & \dots & HP_{S,n\times m} \end{bmatrix}.$$



Russian ice hockey playing environment[5]

The assessment is done to evaluate the competitor location rendering to optimization aim. Beforehand the nominated appropriateness rate can be applied:

$$Z_i = \begin{bmatrix} Z_{1,1,1} & \dots & Z_{1,2,3} \\ \vdots & \ddots & \vdots \\ Z_{n,1,1} & \dots & Z_{n,2,3} \end{bmatrix},$$

where Z_i is used in assessment. Prominent that Z_i is arbitrarily generated for preliminary iteration, whereas for the rest it is obtained from the fresh competitor or player location:

$$Z_{i_{\min}} = \begin{bmatrix} Z_{1_{\min}} \\ Z_{2_{\min}} \\ \vdots \\ Z_{n_{\min}} \end{bmatrix}, \; Z'_j = a\{Z_{i_{\min}}\}.$$

Function's maximum and minimum are defined by

$$O_{\max} = (O_{\max} - O_{\max_{\min}}) / (O_{\max_{\max}} - O_{\max_{\min}}), \quad (1)$$

$$E = (E - E_{\min}) / (E_{\max} - E_{\min}), \quad (2)$$

$$\min \text{fun} = \omega_1 O_{\max} + \omega_2 E, \quad (3)$$

where ω_1, ω_2 are weight.

[5] Available at: https://www.tutorialspoint.com/ice_hockey (accessed: 22.11.2021).

The hockey puck apprising process pretends the delivering of hockey puck from single competitor to the neighbouring competitor. Conversely, in an actual game, there is a probability of a hockey puck gone to the rival team in the course of the transient. In the ORIHO algorithm the probability is ten percentages. Then the streamlining the hockey puck is defined as:

$$p_i' =$$

$$= \begin{cases} R\left(p_i - p_{i+1}\right) + p_i, \ R_N > \text{probability of losing the hockey puck;} \\ p_i - \left(o_1 + R\right)\left(p_i - p_{i+1}\right), R_N \le \text{probability of losing the hockey puck.} \end{cases} \quad (4)$$

Here R_N is arbitrary number, $R_N \in [0,1]$; o_1 determine the hockey puck reflection level; $R_N >$ indicate the successful transient of the hockey puck; $R_N \le$ indicate the unsuccessful transient of the hockey puck.

The competitor or player position is modernized by

$$H_i' = H_i + Ro_2\left(HP_i' - H_i\right) + Ro_3\left(q - H_i\right), \quad (5)$$

o_2 = 1.5 to 2.5; o_3 = 0.5 to 1.5. Bothe o_2, o_3 are responsible for balancing the exploration and exploitation.

The hockey puck apprising is done rendering to possession is given by $HP_{1,1}' = R\left(H_{1,1} - H_{2,1}\right) + H_{1,1}$. Location of the player is rationalized rendering to the position by $H_{1,1}' = H_{1,1} + Ro_2\left(HP_{1,1}' - H_{1,1}\right) + Ro_3\left(H_{n,1} - H_{1,1}\right)$.

Chaotic sequences are integrated into ORIHO algorithm. This incorporation will amplify the exploration and exploitation. Tinkerbell chaotic map [55] engendering standards are implemented:

$$u_{t+1} = u_t^2 - v_t^2 + au_t + bv_t, \quad (6)$$

$$v_{t+1} = 2u_t v_t + cu_t + dv_t, \quad (7)$$

where *a*, *b*, *c*, *d* are non-zero parameters, $a = 0.9$, $b = -0.6$, $c = 2.0$, $d = 0.5$. At primary stage u_0 and $v_0 = 0.1$.

The functional value by linear scaling in Tinkerbell chaotic map is delineated as:

$$u_{t+1}^* = \left(u_{t+1} - \min(u)\right) / \left(\max(u) - \min(u)\right). \quad (8)$$

ORIHO algorithm utilize Laplace distribution to enhance the exploration skill. Then examining the prospect to widen the exploration, a new method endorses stimulating capricious statistics used in formation stage regulator factor in ORIHO algorithm. In the proposed procedure, the exchanging of capricious statistics is done with the illogical numbers stimulated by Laplace distribution to enlarge the assistance of the probability of formation stage in the exploration zone:

$$\text{fun}(v) = \begin{cases} \frac{1}{2}\exp\left(-\left|v-c\right|/d\right), \; b \le c, \\ 1-\frac{1}{2}\exp\left(-\left|v-c\right|/d\right), \; b > c. \end{cases}$$

The probability propagation function of Laplace diffusion is $\text{fun}(v; c, d) = (1/2)v\,\exp\left(-\left|v-c\right|/d\right), \; -\infty < c < \infty,$ where $c \in (-\infty, \infty)$.

Opposition based learning (OBL) is one of the influential approaches to improve the convergence quickness of procedures. The flourishing use of the OBL includes evaluation of opposite populace and dominant populace in the analogous generation to regulate the superior contestant explication. The perception of opposite number requirements is to be delineated to explicate OBL.

Let $O(Z \in [c, d])$ be a palpable figure and the O^o (opposite figure) can be delineated as $O^o = c + d - U$. In the exploration area it has been protracted as $O_i^o = c_i + d_i - U_i$, where $(O_1, O_2, \ldots, O_d)$ indicate dimensional exploration zone; $O_i \in [c_i, d_i]$, $i \to \{1, 2, 3, \ldots, d\}$.

The perception of OBL is employed in the initialization process and in iterations by means of the cohort vaulting level:

a.min f

b. if $f(O^*) \le f(O)$; then $O = O^*$

c. Or else

d.Endure with O in consecutive generations

An opposite component is assimilated after streamlining and produced the distinguished component

$$H_i(iter) = \left(LB_i + UB_i - H_e(iter)\right). \tag{9}$$

Here LB, UB are lower and upper bound.

Mutable speedy parameter (M_s) balances the exploration and exploitation and technically delineated as

$$M_s = M_{\max} - iter_p M_{\max} - M_{\min} / iter_{\max}. \tag{10}$$

The OBL method betrothed rotund the illustrious component and it delineated as

$$H_i(iter) = M_s\left(LB_i + UB_i - H_e(iter)\right). \tag{11}$$

Algorithm

a.Start
b.Fix the parameters values
c.Apply OBL
d.Position of the Russian ice hockey player is initialized
e.Appraise the Russian ice hockey player position
f.Formula (1)
g.Formula (2)
h.Formula (3)
i.Formula (4)
j.Formula (5)
k.Apply Tinkerbell chaotic map
l.Formula (6)
m.Formula (7)
n.Formula (8)
o.Appraise the Russian ice hockey player position
p.Formula (9)
q.Formula (10)
r.Formula (11)
s.Modernize the hockey puck location
t.Streamline the Russian ice hockey player location
u.If end condition met stop or else go to step d
v.End

The computational complexity of ORIHO algorithm is contingent on initialization, aptness assessment, and appraisal of the Russian ice hockey optimization algorithm: $O(TM\ ) + O(TME)$, where T is max iteration; E is dimension of the problem. Over all computation complexity is $O(N(T + TE))$, N, T specify about the count and maximum iterations.

Simulation study. Projected ORIHO algorithm is corroborated in IEEE 30 bus system. In Table 1 show the loss appraisal, Table 2 shows the voltage aberration evaluation and Table 3 gives the L-index assessment.

Table 1

Assessment of tangible power loss (IEEE 30 bus system)

Algorithm	Power loss, MW	Algorithm	Power loss, MW
PSO-TS [10]	4.5213	HAS [13]	4.9059
TS [10]	4.6862	FS [14]	4.5777
PSO [10]	4.6862	HIFS [14]	4.5142

End of the Table 1

Algorithm	Power loss, MW	Algorithm	Power loss, MW
A LOA [11]	4.5900	FS [16]	4.5275
QO-TLBO [12]	4.5594	LISA-I / LISA-II [51]	4.8193 / 4.8547
TLBO [12]	4.5629	SSA [50]	4.5317
GA [13]	4.9408	ISSA [50]	4.5269
SPSO [13]	4.9239	ORIHO	4.3191

Table 2

Assessment of voltage aberration (IEEE 30 bus system)

Algorithm	Voltage deviancy, PU	Algorithm	Voltage deviancy, PU
PSO-TVIW [15]	0.1038	TLBO [12]	0.0913
PSO-TVAC [15]	0.2064	FS [14]	0.1220
PSO-TVAC [15]	0.1354	ISFS [14]	0.0890
PSO-CF [15]	0.1287	S-FS [16]	0.0877
PG-PSO [15]	0.1202	LISA-I [49]	0.374
SWT-PSO [15]	0.1614	LISA-II [49]	0.377
PGSWT-PSO [15]	0.1539	SSA [48]	0.0854
MPG-PSO [15]	0.0892	ISSA [48]	0.0831
QO-TLBO [12]	0.0856	ORIHO	0.0819

Table 3

Appraisal of voltage constancy (IEEE 30 bus system)

Algorithm	Voltage constancy, PU	Algorithm	Voltage constancy, PU
PSO-TVIW [15]	0.1258	TLBO [12]	0.1180
PSO-TVAC [15]	0.1499	ALO [11]	0.1161
PSO-TVAC [15]	0.1271	ABC [11]	0.1161
PSO-CF [15]	0.1261	GWO [11]	0.1242
PG-PSO [15]	0.1264	BA [11]	0.1252
SWT-PSO [15]	0.1488	FS [14]	0.1252
PGSWT-PSO [15]	0.1394	IS-FS [14]	0.1245
MPG-PSO [15]	0.1241	BFS [16]	0.1007
QO-TLBO [12]	0.1191	ORIHO	0.1001

Projected ORIHO algorithm is corroborated in IEEE 57 bus system. Tables 4 and 5 show the loss appraisal, voltage aberration evaluation, Table 6 give the power constancy assessment.

Table 4

Appraisal of power loss (IEEE 57 bus system)

Algorithm	Power loss, MW	Algorithm	Power loss, MW
ICOA [46]	22.376	MOPSO [49]	27.83
ICOA1 [46]	22.383	MOEPSO [47]	27.42
WCA [46]	26.0402	MFO [50]	24.25
SSA [46]	25.3854	MOGWA [51]	21.171
SFOA [46]	26.6541	SGA [52]	25.64
COA [46]	24.5358	PSO [52]	25.03
LISA-I [48] / LISA-II [49]	26.88 / 26.92	HAS [52]	24.90
ISA [49]	26.97	ORIHO	20.201

Table 5

Voltage aberration evaluation (IEEE 57 bus system)

Algorithm	VD, PU	Algorithm	VD, PU
ICOA [46]	0.6051	LISA-I [49]	1.0642
ICOA1[46]	0.6155	LISA-II [49]	1.072
WCA [46]	0.7309	ISA [49]	1.0912
SSA [46]	0.94	MOPSO [47]	1.10
SFOA [46]	0.7913	MOEPSO [47]	0.896
COA [46]	0.6711	ORIHO	0.6018

Table 6

Power constancy assessment (IEEE 57 bus system)

Algorithm	ICOA [46]	ICOA1 [46]	WCA [46]	SSA [46]	SFOA [46]	COA [46]	ORIHO
Voltage stability index	0.25169	0.2583	0.2789	0.29	0.2831	0.2757	0.2151

Projected ORIHO algorithm is corroborated in IEEE 118 bus system. Table 7 shows the loss appraisal, Table 8 shows the voltage aberration evaluation and Table 9 gives the power constancy assessment.

Table 7

Power loss appraisal (IEEE 118 bus system)

Algorithm	Power loss, MW	Algorithm	Power loss, MW
ICOA [46]	114.8036	COA2[46]	126.0426
ICOA1[46]	114.8623	LISA-I [49]	119.79
WCA [46]	118.3207	LISA-II [49]	120.15

End of the Table 7

Algorithm	Power loss, MW	Algorithm	Power loss, MW
SSA [46]	125.7288	ISA [49]	120.67
SFOA [46]	125.6801	ALCPSO [53]	121.53
COA [46]	132.3341	CLPSO [53]	130.96
COA1[46]	123.6867	ORIHO	114.08

Table 8

Voltage aberration evaluation (IEEE 118 bus system)

Algorithm	VD, PU	Algorithm	VD, PU
ICOA [46]	0.1605	COA1 [46]	0.1928
ICOA1[46]	0.1608	COA2 [46]	0.1936
WCA [46]	0.2315	LISA-I [49]	0.2819
SSA [46]	0.4883	LISA-II [49]	0.2876
SFOA [46]	0.6061	ISA [49]	0.2948
COA [46]	0.2034	ORIHO	0.1608

Table 9

Power constancy assessment (IEEE 118 bus system)

Algorithm	Voltage stability index	Algorithm	Voltage stability index
ICOA [46]	0.06061	SFOA [46]	0.0619
ICOA1 [46]	0.06064	COA [46]	0.06123
WCA [46]	0.060731	COA1 [46] / COA2 [46]	0.06072 / 0.06077
SSA [46]	0.0639	ORIHO	0.06011

Projected ORIHO algorithm is corroborated in IEEE 300 bus system. Table 10 shows the loss appraisal and the voltage aberration evaluation.

Table 10

Power loss appraisal, and voltage aberration evaluation (IEEE 300 bus system)

Parameter	Algorithm				
	LISA-I [49]	LISA-II [49]	ISA [49]	MOALO [47]	ORIHO
Power loss, MW	396.983	397.236	397.902	398.853	390.006
VD, PU	5.9324	5.9416	5.9613	6.0169	5.7501

Projected ORIHO algorithm is corroborated in IEEE 354 bus system. In Table 11 shows the loss appraisal and the voltage aberration evaluation.

Table 11

Power loss appraisal, and voltage aberration (IEEE 354 bus system)

Parameter	Algorithm					
	LISA-I [49]	LISA-II [49]	ISA [49]	FAHCLSO [47]	PSO [47]	ORIHO
Power loss, MW	337.374	338.715	339.325	341.001	341.123	336.108
VD, PU	0.4978	0.5117	0.5216	0.5354	0.6395	0.4512

Below shows the time taken for IEEE 30, 57, 118, 300 and 354 bus test systems:

IEEE bus system	30	57	118	300	354
Time, s	29.01	32.14	42.02	78.13	88.23

Conclusion. Proposed ORIHO algorithm abridged the loss ingeniously. The competitor or player location signifies the contender solution. In the interim, the hockey puck location is the elucidation vector that will control the locus of the subsequent competitor. Moreover, players characterize a set of elucidation. Chaotic sequences are integrated into ORIHO algorithm. This incorporation will amplify the exploration and exploitation. Tinkerbell chaotic map engendering standards are implemented. Opposition based learning is one of the influential approaches to improve the convergence quickness of procedures. The flourishing use of the OBL includes evaluation of opposite populace and dominant populace in the analogous generation to regulate the superior contestant explication. The perception of opposite number requirements is to be delineated to explicate OBL. ORIHO algorithm utilize Laplace distribution to enhance the exploration skill. Then examining the prospect to widen the exploration, a new method endorses stimulating capricious statistics used in formation stage regulator factor in ORIHO algorithm. In the proposed procedure, the exchanging of capricious statistics is done with the illogical numbers stimulated by Laplace distribution to enlarge the assistance of the probability of formation stage in the exploration zone. Proposed ORIHO algorithm is corroborated in IEEE 30, 57, 118, 300 and 354 bus test systems. True power loss lessening, power divergence curtailing, and power constancy augmentation has been achieved.

REFERENCES

[1] Zhu J.Z., Xiong X.F. Optimal reactive power control using modified interior point method. *Electr. Power Syst. Res.*, 2003, vol. 66, iss. 2, pp. 187–192.
DOI: https://doi.org/10.1016/S0378-7796(03)00078-6

[2] Quintana V.H., Santos-Nieto M. Reactive-power dispatch by successive quadratic programming. *IEEE Trans. Energy Convers*., 1989, vol. 4, iss. 3, pp. 425–435. DOI: https://doi.org/10.1109/60.43245

[3] Jan R.-M., Chen N. Application of the fast Newton — Raphson economic dispatch and reactive power/voltage dispatch by sensitivity factors to optimal power flow. *IEEE Trans. Energy Convers*., 1995, vol. 10, iss. 2, pp. 293–301. DOI: https://doi.org/10.1109/60.391895

[4] Terra L.D.B., Short M.J. Security-constrained reactive power dispatch. *IEEE Trans. Power Syst*., 1991, vol. 6, iss. 1, pp. 109–117. DOI: https://doi.org/10.1109/59.131053

[5] Grudinin N. Reactive power optimization using successive quadratic programming method. *IEEE Trans. Power Syst*., 1998, vol. 13, iss. 4, pp. 1219–1225. DOI: https://doi.org/10.1109/59.736232

[6] Ebeed M., Alhejji A., Kamel S., et al. Solving the optimal reactive power dispatch using marine predators algorithm considering the uncertainties in load and wind-solar generation systems. *Energies*, 2020, vol. 13, iss. 17, art. 4316. DOI: https://doi.org/10.3390/en13174316

[7] Sahli Z., Hamouda A., Bekrar A., et al. Reactive power dispatch optimization with voltage profile improvement using an efficient hybrid algorithm. *Energies*, 2018, vol. 11, iss. 8, art. 2134. DOI: https://doi.org/10.3390/en11082134

[8] Davoodi E., Babaei E., Mohammadi-Ivatloo B., et al. A novel fast semidefinite programming-based approach for optimal reactive power dispatch. *IEEE Trans. Industr. Inform*., 2020, vol. 16, iss. 1, pp. 288–298. DOI: https://doi.org/10.1109/TII.2019.2918143

[9] Bingane C., Anjos M.F., Le Digabel S. Tight-and-cheap conic relaxation for the optimal reactive power dispatch problem. *IEEE Trans. Power Syst.,* 2019, vol. 34, iss. 6, pp. 4684–4693. DOI: https://doi.org/10.1109/TPWRS.2019.2912889

[10] Sahli Z., Hamouda A., Bekrar A., et al. Hybrid PSO-tabu search for the optimal reactive power dispatch problem. *IECON*, 2014, pp. 3536–3542. DOI: https://doi.org/10.1109/IECON.2014.7049024

[11] Mouassa S., Bouktir T., Salhi A. Ant lion optimizer for solving optimal reactive power dispatch problem in power systems. *Eng. Sci. Technol. an Int. J*., 2017, vol. 20, iss. 3, pp. 885–895. DOI: https://doi.org/10.1016/j.jestch.2017.03.006

[12] Mandal B., Roy P.K. Optimal reactive power dispatch using quasi-oppositional teaching learning based optimization. *Int. J. Electr. Power Energy Syst*., 2013, vol. 53, pp. 123–134. DOI: https://doi.org/10.1016/j.ijepes.2013.04.011

[13] Khazali H., Kalantar M. Optimal reactive power dispatch based on harmony search algorithm. *Int. J. Electr. Power Energy Syst*., 2011, vol. 33, iss. 3, pp. 684–692. DOI: https://doi.org/10.1016/j.ijepes.2010.11.018

[14] Tran H.V., Pham T.V., Pham L.H., et al. Finding optimal reactive power dispatch solutions by using a novel improved stochastic fractal search optimization algorithm. *TELKOMNIKA*, 2019, vol. 17, no. 5, pp. 2517–2526. DOI: http://doi.org/10.12928/telkomnika.v17i5.10767

[15] Polprasert J., Ongsakul W., Dieu V.N. Optimal reactive power dispatch using improved pseudo-gradient search particle swarm optimization. *Electr. Power Compon. Syst.*, 2016, vol. 44, iss. 5, pp. 518–532.
DOI: https://doi.org/10.1080/15325008.2015.1112449

[16] Duong T.L., Duong M.Q., Phan V.-D., et al. Optimal reactive power flow for large-scale power systems using an effective metaheuristic algorithm. *J. Electr. Comput. Eng.*, 2020, vol. 2020, art. 6382507. DOI: https://doi.org/10.1155/2020/6382507

[17] Raghuwanshi B.S., Shukla S. Class imbalance learning using UnderBagging based kernelized extreme learning machine. *Neurocomputing*, 2019, vol. 329, pp. 172–187. DOI: https://doi.org/10.1016/j.neucom.2018.10.056

[18] Yu X., Feng Y., Gao Y., et al. Dual-weighted kernel extreme learning machine for hyperspectral imagery classification. *Remote Sens.*, 2021, vol. 13, iss. 3, art. 508.
DOI: https://doi.org/10.3390/rs13030508

[19] Lv F., Han M. Hyperspectral image classification based on multiple reduced kernel extreme learning machine. *Int. J. Mach. Learn. Cybern.*, 2019, vol. 10, iss. 6, pp. 3397–3405. DOI: https://doi.org/10.1007/s13042-019-00926-5

[20] Dai C., Chen W., Zhu Y., et al. Seeker optimization algorithm for optimal reactive power dispatch. *IEEE Trans. Power Syst.*, 2009, vol. 24, iss. 3, pp. 1218–1231.
DOI: https://doi.org/10.1109/TPWRS.2009.2021226

[21] Subbaraj P., Rajnarayan P.N. Optimal reactive power dispatch using self-adaptive real coded genetic algorithm. *Electr. Pow. Syst. Res.*, 2009, vol. 79, iss. 2, pp. 374–381. DOI: https://doi.org/10.1016/j.epsr.2008.07.008

[22] Pandya S., Roy R. Particle swarm optimization based optimal reactive power dispatch. *Proc. ICECCT*, 2015. DOI: https://doi.org/10.1109/ICECCT.2015.7225981

[23] Hussain A.N., Abdullah A.A., Neda O.M. Modified particle swarm optimization for solution of reactive power dispatch. *Res. J. Appl. Sci. Eng. Technol.*, 2018, vol. 15, iss. 8, pp. 316–327. DOI: http://dx.doi.org/10.19026/rjaset.15.5917

[24] Vishnu M., Kumar T.K.S. An improved solution for reactive power dispatch problem using diversity-enhanced particle swarm optimization. *Energies*, 2020, vol. 13, iss. 11, art. 2862. DOI: https://doi.org/10.3390/en13112862

[25] Omelchenko I.N., Lyakhovich D.G., Aleksandrov A.A., et al. Development of a design algorithm for the logistics system of product distribution of the mechanical engineering enterprise. *Herald of the Bauman Moscow State Technical University, Series Mechanical Engineering*, 2020, no. 3 (132), pp. 62–69 (in Russ.).
DOI: https://doi.org/10.18698/0236-3941-2020-3-62-69

[26] Omelchenko I.N., Zakharov M.N., Lyakhovich D.G., et al. [Organization of logistic systems of scientific productions: scientific research work of the master's student and evaluation of its results]. *Sistemy upravleniya polnym zhiznennym tsiklom vysokotekhnologichnoy produktsii v mashinostroenii: novye istochniki rosta. Mater. III Vseros. nauch.-prakt. konf.* [Organisation of Logistics Systems for Knowledge-Intensive Industries: Master's Student Research Work and Evaluation. Proc. III Russ. Sci.-Pract. Conf.]. Moscow, Pervoe ekonomicheskoe izdatelstvo Publ., 2020, pp. 252–256 (in Russ.).
DOI: https://doi.org/10.18334/9785912923258.252-256

[27] Omelchenko I.N., Lyakhovich D.G., Aleksandrov A.A., et al. [Problems and organizational and technical solutions of processing management problems of material and technical resources in a design-oriented organization]. *Sistemy upravleniya polnym zhiznennym tsiklom vysokotekhnologichnoy produktsii v mashinostroenii: novye istochniki rosta. Mater. III Vseros. nauch.-prakt. konf.* [Management systems for the full life cycle of high-tech products in mechanical engineering: new sources of growth. Proc. III All-Russ. Sci. Pract. Conf.]. Moscow, Pervoe ekonomicheskoe izdatelstvo Publ., 2020, pp. 257–260 (in Russ.). DOI: https://doi.org/10.18334/9785912923258.257-260

[28] Khunkitti S., Siritaratiwat A., Premrudeepreechacharn S. Multi-objective optimal power flow problems based on slime mould algorithm. *Sustainability*, 2021, vol. 13, iss. 13, art. 7448. DOI: https://doi.org/10.3390/su13137448

[29] Diab H., Abdelsalam M., Abdelbary A. A multi-objective optimal power flow control of electrical transmission networks using intelligent meta-heuristic optimization techniques. *Sustainability*, 2021, vol. 13, iss. 9, art. 4979.
DOI: https://doi.org/10.3390/su13094979

[30] Surender R.S. Optimal reactive power scheduling using cuckoo search algorithm. *IJECE*, 2017, vol. 7, no. 5, pp. 2349–2356.
DOI: http://doi.org/10.11591/ijece.v7i5.pp2349-2356

[31] Reddy S.S., Bijwe P.R., Abhyankar A.R. Faster evolutionary algorithm based optimal power flow using incremental variables. *Int. J. Electr. Power Energy Syst.*, 2014, vol. 54, pp. 198–210. DOI: https://doi.org/10.1016/j.ijepes.2013.07.019

[32] Sridhar N., Kowsalya M. Enhancement of power management in micro grid system using adaptive ALO technique. *J. Ambient Intell. Human. Comput.*, 2021, vol. 12, no. 2, pp. 2163–2182. DOI: https://doi.org/10.1007/s12652-020-02313-3

[33] Suja K.R. Mitigation of power quality issues in smart grid using levy flight based moth flame optimization algorithm. *J. Ambient Intell. Human. Comput.*, 2021, vol. 12, no. 10, pp. 9209–9228. DOI: https://doi.org/10.1007/s12652-020-02626-3

[34] Darvish Falehi A. Optimal robust disturbance observer based sliding mode controller using multi-objective grasshopper optimization algorithm to enhance power system stability. *J. Ambient Intell. Human. Comput.*, 2020, vol. 11, no. 11, pp. 5045–5063. DOI: https://doi.org/10.1007/s12652-020-01811-8

[35] Sharma S., Ghosh S. FIS and hybrid ABC-PSO based optimal capacitor placement and sizing for radial distribution networks. *J. Ambient Intell. Human. Comput.*, 2020, vol. 11, no. 2, pp. 901–916. DOI: https://doi.org/10.1007/s12652-019-01216-2

[36] Bentouati B., Khelifi A., Shaheen A.M., et al. An enhanced moth-swarm algorithm for efficient energy management based multi dimensions OPF problem. *J. Ambient Intell. Human. Comput.*, 2021, vol. 12, no. 10, pp. 9499–9519.
DOI: https://doi.org/10.1007/s12652-020-02692-7

[37] Menon P.C., Rani B.K., Kumar K., et al. An effective OS–DPLL design for reducing power dissipation in an IoT application. *J. Ambient Intell. Human. Comput.*, 2021.
DOI: https://doi.org/10.1007/s12652-021-03016-z

[38] Saxena N.K., Kumar A., Gupta V. Enhancement of system performance using STATCOM as dynamic compensator with squirrel cage induction generator (SCIG) based microgrid. *Int. J. Emerg. Electr. Power Syst.*, 2021, vol. 22, iss. 2, pp. 177–189. DOI: https://doi.org/10.1515/ijeeps-2020-0228

[39] Kazmi S.A., Shahzad M., Shin D. Voltage stability index for distribution network connected in loop configuration. *IETE J. Res.*, 2017, vol. 63, iss. 2, pp. 281–293. DOI: https://doi.org/10.1080/03772063.2016.1257376

[40] Sambaiah K.S., Jayabarathi T. Optimal modeling and allocation of mixed wind and solar generation systems in electric distribution networks. *IETE J. Res.*, 2020, vol. 68, iss. 6, pp. 4129–4141. DOI: https://doi.org/10.1080/03772063.2020.1787876

[41] Zaidan M.R., Toos S.I. Optimal location of static var compensator to regulate voltage in power system. *IETE J. Res.*, 2021, vol. 69, iss. 4, pp. 2177–2185. DOI: https://doi.org/10.1080/03772063.2021.1886877

[42] Lakshmi Priya J., Jaya Christa S.T. An effective hybridized GWO-BSA for resolving optimal power flow problem with the inclusion of unified power flow controller. *IETE J. Res.*, 2021, vol. 69, iss. 7, pp. 4605–4617. DOI: https://doi.org/10.1080/03772063.2021.1942245

[43] Ahmadnia S., Tafehi E., Shakhsi Dastgahian F. Optimal placement and sizing for solar farm with economic evaluation, power line loss and energy consumption reduction. *IETE J. Res.*, 2019, vol. 68, iss. 3, pp. 2175–2190. DOI: https://doi.org/10.1080/03772063.2019.1694450

[44] Ashpazi M.A., Mohammadi-Ivatloo B., Zare K., et al. Probabilistic allocation of thyristor-controlled phase shifting transformer for transient stability enhancement of electric power system. *IETE J. Res.*, 2015, vol. 61, iss. 4, pp. 382–391. DOI: https://doi.org/10.1080/03772063.2015.1023743

[45] Juneja K. A fuzzy-controlled differential evolution integrated static synchronous series compensator to enhance power system stability. *IETE J. Res.*, 2020, vol. 68, iss. 6, pp. 4437–4452. DOI: https://doi.org/10.1080/03772063.2020.1795936

[46] Kien L.C., Hien C.T., Nguyen T.T. Optimal reactive power generation for transmission power systems considering discrete values of capacitors and tap changers. *App. Sci.*, 2021, vol. 11, iss. 12, art. 5378. DOI: https://doi.org/10.3390/app11125378

[47] Mouassa S., Bouktir T. Multi-objective ant lion optimization algorithm to solve large-scale multi-objective optimal reactive power dispatch problem. *COMPEL*, 2018, vol. 38, no. 1, pp. 304–324. DOI: https://doi.org/10.1108/COMPEL-05-2018-0208

[48] Tudose A., Picioroaga I., Sidea D., et al. Solving single- and multi-objective optimal reactive power dispatch problems using an improved salp swarm algorithm. *Energies*, 2021, vol. 14, iss. 5, art. 1222. DOI: https://doi.org/10.3390/en14051222

[49] Karthik N., Parvathy A.K., Arul R. Multi-objective optimal reactive power dispatch using levy interior search algorithm. *IJEEI*, 2020, vol. 12, no. 3, pp. 547–570. DOI: https://doi.org/10.15676/ijeei.2020.12.3.8

[50] Mei R.N.S., Sulaiman M.H., Mustaffa Z., et al. Optimal reactive power dispatch solution by loss minimization using moth-flame optimization technique. *Appl. Soft Comput.*, 2017, vol. 59, pp. 210–222. DOI: https://doi.org/10.1016/j.asoc.2017.05.057

[51] Nuaekaew K., Artrit P., Pholdee N., et al. Optimal reactive power dispatch problem using a two-archive multi-objective grey wolf optimizer. *Expert Syst. Appl.*, 2017, vol. 87, pp. 79–89. DOI: https://doi.org/10.1016/j.eswa.2017.06.009

[52] Khazali A.H., Kalantar M. Optimal reactive power dispatch based on harmony search algorithm. *Int. J. Electr. Power Energy Syst.*, 2011, vol. 33, iss. 3, pp. 684–692. DOI: https://doi.org/10.1016/j.ijepes.2010.11.018

[53] Chen G., Liu L., Guo Y., et al. Multi-objective enhanced PSO algorithm for optimizing power losses and voltage deviation in power systems. *COMPEL*, 2016, vol. 35, no. 1, pp. 350–372. DOI: https://doi.org/10.1108/COMPEL-02-2015-0030

[54] Zou Q., Li A., He X., et al. Optimal operation of cascade hydropower stations based on chaos cultural sine cosine algorithm. *IOP Conf. Ser.: Mater. Sci. Eng.*, 2018, vol. 366, art. 012005. DOI: http://dx.doi.org/10.1088/1757-899X/366/1/012005

[55] Inoue K., Ohya M., Sato K. Application of chaos degree to some dynamical systems. *Chaos Solitons Fractals*, 2000, vol. 11, iss. 9, pp. 1377–1385.
DOI: https://doi.org/10.1016/S0960-0779(99)00050-8

[56] Dinkar S.K., Deep K. Opposition based Laplacian ant lion optimizer. *J. Comput. Sci.*, 2017, vol. 23, pp. 71–90. DOI: https://doi.org/10.1016/j.jocs.2017.10.007

Kanagasabai L. — Dr. Sc. (Full), Professor, Department of Electrical and Electronics Engineering, Prasad V. Potluri Siddhartha Institute of Technology (Kanuru, Vijayawada, Andhra Pradesh, 520007 India).

Please cite this article as:

Kanagasabai L. Opposition based Russian ice hockey optimization algorithm for power loss lessening and stability amplification. *Herald of the Bauman Moscow State Technical University, Series Natural Sciences*, 2025, no. 1 (118), pp. 82–99.
EDN: FEQTXE