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Real Power Loss Reduction by Hybridization of Tree-Seed Algorithm with Sine-Cosine Algorithm

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Abstract

In this work, real power loss has done through hybridized Tree-seed algorithm. Sine-cosine algorithm which has been combined with Tree-seed algorithm (HTS) is projected to solve the problem. Tree-seed algorithm is based on the relationship between trees and seeds. And Sine Cosine Algorithm is based on the functions of Sine and Cosine; it stimulates the leader variable agent solutions towards the most excellent solution. In this work, seed engendering mechanism has been enhanced through adaptive mode and with reference to the iterations a linearly (k) varying mechanism has been implemented to perk up the exploration and exploitation. With considering voltage stability index proposed hybridized Tree-seed algorithm (HTS) is tested in IEEE 30, bus system. Then, the Proposed hybridized Tree-seed algorithm has been tested in standard IEEE 14, 30, 57, 118, 300 bus test systems without considering the voltage stability index. In first analysis with considering voltage stability index real power loss minimization, voltage deviation minimization, and voltage stability index enhancement has been attained. In the second evaluation without considered voltage stability index, also power loss reduction achieved. Percentage of power loss reduction is 15.80%, 20.74%, 26.29%, and 14.55% with respect to the base value. Power Loss comparison has been done with other standard methods.

Keywords

Optimal Reactive Power, Transmission Loss, Tree-Seed, Sine-Cosine

1. Introduction

Minimization of real power loss, voltage stability improvement and deviation of voltage are the main objectives in this work. Many conventional methods like Newton's method, interior point method; successive quadratic programming method [1-6] and evolutionary algorithms like gravitational search, particle swarm optimization, symbiotic organism search algorithm [7-48] are utilized to solve the problem. Conventional methods faced difficulty in handling the constraints. Evolutionary methods have to balance the exploration and exploitation then only optimal solution can be obtained. Many algorithm fail to balance the exploration and exploitation. In this work, Tree-seed algorithm has been combined with sine-cosine algorithm (HTS) to solve the problem. Tree-seed algorithm modeling is based on the tree, seed and during the search a converse association has been preserved between the exploration and exploitation. Sine Cosine Algorithm is based on the functions of Sine and Cosine and it induce prime variable agent towards best solution. Tree location has been taken into consideration where seeds are produced and also it will be as best location for the trees. In explore of the optimal values, dispersal of the seeds is very crucial and it is not possible to engender the seeds are not easy in capricious mode. So the number of seeds updating will start from highest and will be gradually reduced to minimum level. Then a novel linear parameter “K” has been employed which has been stimulated from sine cosine algorithm which persuades the solution to jump out from local environment. Hybridization of Tree-seed algorithm with sine-cosine algorithm will improve the exploration and exploitation effectively. Proposed Tree-seed algorithm has been combined with sine-cosine algorithm (HTS) is tested in IEEE 30, bus system with considering voltage stability evaluation index. Then the Proposed Tree-seed algorithm has been combined with sine-cosine algorithm (HTS) has been tested in standard IEEE 14, 30, 57, 118, 300 bus test systems without considering the voltage stability index. Power loss and voltage deviation minimization has been achieved with enhancement of voltage stability index.

2. Problem Formulation

Objective function defined as,

$$Minimization\tilde{F}(\bar{x},\bar{y}) \tag{1}$$

Subject to

$$E(\bar{x},\bar{y}) = 0 \tag{2}$$

$$I(\bar{x},\bar{y}) = 0 \tag{3}$$

$$x = \left[VG_1,..,VG_{Ng};QC_1,..,QC_{Nc};T_1,..,T_{N_T}\right] \tag{4}$$

$$y = \left[PG_{slack};VL_1,..,VL_{N_{Load}};QG_1,..,QG_{Ng};SL_1,..,SL_{N_T}\right] \tag{5}$$

Fitness function (OF_1) is defined to diminish the power loss (MW) is,

$$OF_1 = P_{Min} = Min\left[\sum_m^{NTL} G_m\left[V_i^2 + V_j^2 - 2 * V_i V_j cos\text{Ø}_{ij}\right]\right] \tag{6}$$

Fitness function $(OF_2)$for minimization of voltage deviation minimization,

$$OF_2 = Min\left[\sum_{i=1}^{N_{LB}}\left|V_{Lk} - V_{Lk}^{desired}\right|^2 + \sum_{i=1}^{Ng}\left|Q_{GK} - Q_{KG}^{Lim}\right|^2\right] \tag{7}$$

Fitness function (OF_3) for voltage stability index value,

$$OF_3 = MinL_{Max} \tag{8}$$

$$L_{Max} = Max\left[L_j\right]; j = 1; N_{LB} \tag{9}$$

$$\begin{cases} L_j = 1 - \sum_{i=1}^{NPV} F_{ji}\frac{V_i}{V_j} \\ F_{ji} = -[Y_1]^1[Y_2] \end{cases} \tag{10}$$

$$L_{Max} = Max\left[1 - [Y_1]^{-1}[Y_2] \times \frac{V_i}{V_j}\right] \tag{11}$$

Equality constraints

$$0 = PG_i - PD_i - V_i\sum_{j \in N_B} V_j\left[G_{ij}cos\left[\text{Ø}_i - \text{Ø}_j\right] + B_{ij}sin\left[\text{Ø}_i - \text{Ø}_j\right]\right] \tag{12}$$

$$0 = QG_i - QD_i - V_i\sum_{j \in N_B} V_j\left[G_{ij}sin\left[\text{Ø}_i - \text{Ø}_j\right] + B_{ij}cos\left[\text{Ø}_i - \text{Ø}_j\right]\right] \tag{13}$$

Inequality constraints

$$\mathbf{P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max}} \tag{14}$$

$$\mathbf{Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g} \tag{15}$$

$$\mathbf{VL_i^{min} \leq VL_i \leq VL_i^{max}, i \in NL} \tag{16}$$

$$\mathbf{T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T} \tag{17}$$

$$\mathrm{Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C} \tag{18}$$

$$|SL_i| \le S_{L_i}^{max} \text{ , i} \in \mathrm{N_{TL}} \tag{19}$$

$$\mathrm{VG_i^{min}} \le \mathrm{VG_i} \le \mathrm{VG_i^{max}} \text{ , i} \in \mathrm{N_g} \tag{20}$$

Multi objective fitness (MOF) function is,

$$MOF = OF_1 + x_i OF_2 + yOF_3 = OF_1 + \left[\sum_{i=1}^{NL} x_v \left[VL_i - VL_i^{min}\right]^2 + \sum_{i=1}^{NG} x_g \left[QG_i - QG_i^{min}\right]^2\right] + x_f OF_3 \tag{21}$$

$$VL_i^{min} = \begin{cases} VL_i^{max} \text{ }, VL_i > VL_i^{max} \\ VL_i^{min}, VL_i < VL_i^{min} \end{cases} \tag{22}$$

$$QG_i^{min} = \begin{cases} QG_i^{max} \text{ }, QG_i > QG_i^{max} \\ QG_i^{min}, QG_i < QG_i^{min} \end{cases} \tag{23}$$

3. Hybridization of Tree-Seed Algorithm with Sine-Cosine Algorithm

In this work, Tree-seed algorithm has been combined with sine-cosine algorithm (HTC) for power loss reduction. Tree-seed algorithm is based on the association between trees and seeds. Many problems have been solved by the Tree-seed algorithm effectively but it lacks in the global searching and also there is limitation in the exploitation also. In order to overcome these defects, Tree-seed algorithm has been combined with sine-cosine algorithm for solving the problem. Sine Cosine Algorithm is based on the functions of Sine and Cosine; it excites principal variable agent solutions and it sways externally or inner mode towards the most excellent solution. In this work, seed engendering mechanism has been improved in adaptive mode and with respect to the iterations a linearly (k) varying mechanism has been implemented.

Tree-seed algorithm modeling is based on the tree, seed and during searching an inverse correlation has been maintained between the exploration and exploitation.

$$f(\vec{G}) \le f(\vec{H}), \forall \vec{H} \in P \tag{24}$$

$$f(\vec{G}) \ge f(\vec{H}), \forall \vec{H} \in P \tag{25}$$

Where "f" the objective function and “P” is the solutions which are suitable.

Tree position has been taken into consideration where seeds are engendered and also it will be as most excellent location for the population of the trees [44-47]. Then the updating equation can be mathematically written as,

$$Dm_{i,j} = Trd_{i,j} + \alpha_{i,j} \times \left(C_j - Tr_{e,j}\right) \tag{26}$$

$$Dm_{i,j} = Trd_{i,j} + \alpha_{i,j} \times \left(Trd_{i,j} - Tr_{e,j}\right) \tag{27}$$

Where $Dm_{i,j}$ is the ith seeds jth dimension, $Trd_{i,j}$ is the ith tree jth dimension, C_j is the most excellent jth tree location or position obtained, $Tr_{e,j}$ is the rth tree in jth dimension arbitrarily chosen from the population , $\alpha_{i,j}$ is the scaling factor from [-1, 1].

In the algorithm, preliminary tree locations or positions will be the beginning of the exploration procedure and it engendered by,

$$Trd_{i,j} = Lower\ bound_{j,min} + Random_{i,j} \times \left(Higher\ bound_{j,max} - Lower\ bound_{j,min}\right) \tag{28}$$

Where $Lower\ bound_{j,min}$ the lower limit of the exploration space is, $Higher\ bound_{j,max}$ is the maximum limit of the exploration space, $Random_{i,j}$ is the number arbitrarily produced in range of [0, 1].

From the population, the best solution has been selected to comprehend the minimization by,

$$C = minimum\left(f\left(\overrightarrow{Tr_i}\right)\right) \tag{29}$$

Then, the maximum number of function evaluation is given by,

$$Maximum\ function\ evaluation = Dimensionality \times 10000 \tag{30}$$

a. Start;
b. Set the preliminary values and end criterion
c. In the exploration space engender “N” trees arbitrarily

$$Trd_{i,j} = Lower\ bound_{j,min} + Random_{i,j} \times \left(Higher\ bound_{j,max} - Lower\ bound_{j,min}\right)$$

d. Then, the most excellent solution obtained so far will be saved

$$C = minimum\left(f\left(\overrightarrow{Tr_i}\right)\right)$$

e. For every tree number of seeds to be produced should be determined
f. Is $random < ST$?
g. If Yes update the dimension by,

$$Dm_{i,j} = Trd_{i,j} + \alpha_{i,j} \times \left(C_j - Tr_{e,j}\right)$$

h. If No update the dimension by

$$Dm_{i,j} = Trd_{i,j} + \alpha_{i,j} \times \left(Trd_{i,j} - Tr_{e,j}\right)$$

i. Is passing through each seed of every tree?
j. If Yes then choose the most excellent seed and compare with the tree
k. If No the go to step "f"
l. Is the value of the objective function better than preceding one?
m. If yes then the position of the seeds are the alternate for the trees
n. If No form the population choose the most excellent solution by,

$$C = minimum\left(f\left(\overrightarrow{Tr_i}\right)\right)$$

o. Is the new most excellent solution better than preceding one?
p. If Yes then new most excellent solution will substitute the preceding solution
q. If No then the preceding solution is the most excellent one
r. Is the end condition satisfied?
s. If Yes then report the most excellent solution
t. If No then go to step "e"
u. End

Sine Cosine Algorithm based on Sine and Cosine functions ; it produces preliminary arbitrary agent solutions and it swing outwardly or inward towards the most excellent solution by using numerical model which based on sine and cosine functions [48].

$$\vec{X}_i^{t+1} = \vec{X}_i^t + random_1 \times sin(random_2) \times \left|random_3 \times I_i^t - \vec{X}_i^t\right| \tag{31}$$

$$\vec{X}_i^{t+1} = \vec{X}_i^t + random_1 \times cos(random_2) \times \left|random_3 \times I_i^t - \vec{X}_i^t\right| \tag{32}$$

$$\vec{X}_i^{t+1} = \begin{cases} \vec{X}_i^t + random_1 \times sin(random_2) \times \left|random_3 \times I_i^t - \vec{X}_i^t\right| random_4 < 0.5 \\ \vec{X}_i^t + random_1 \times cos(random_2) \times \left|random_3 \times I_i^t - \vec{X}_i^t\right| random_4 \geq 0.5 \end{cases} \tag{33}$$

a. Start
b. Initialize the search agents
c. $Is\ t < maximum\ number\ of\ iterations$?
d. If Yes agents are evaluated based on the fitness values
e. Then update the most excellent solution
f. Modernize the parameters
g. Then the position of the search agents are updated by

$$\vec{X}_i^{t+1} = \vec{X}_i^t + random_1 \times sin(random_2) \times \left|random_3 \times I_i^t - \vec{X}_i^t\right|$$

$$\vec{X}_i^{t+1} = \vec{X}_i^t + random_1 \times cos(random_2) \times \left|random_3 \times I_i^t - \vec{X}_i^t\right|$$

h. If No then report the most excellent solution obtained so far
i. End

In search of the optimal values of spreading of seeds is very essential and it is not possible to stimulate the seeds are not easy in arbitrary mode. So the number of seeds updating will start from maximum and will be steadily reduced.

Then the maximum function evaluation written as

$$Ratio\ of\ \text{maximum function evaluation} = \frac{\text{function evaluation}}{\text{maximum function evaluation}} \tag{34}$$

$$GTheatv = 0.50 \times Ratio\ \text{function evaluation} \times \pi \tag{35}$$

$$Number\ of\ seeds = Lower\ bound + |(Higher\ bound - Lower\ bound) \times Cos(GTheatv)| + 1.0 \tag{36}$$

By changing the number of seeds, the global exploration capability is greatly improved.

Then a new linear parameter "K" has been implemented and it inspired from sine cosine algorithm which induces the solution to jump out from local environment. At first in the process, exploration has been improved then gradually exploitation will be enhanced.

$$k = 2.0 \times (1 - Ratio\ \text{function evaluation}) \tag{37}$$

Then in the Hybridization Tree-seed algorithm with sine-cosine algorithm, the location or the position of the seed is obtained from the tree is very key for the exploration procedure. Then the exploration equation is given by,

$$Dm_{i,j} = Random \times Tr_{i,j} + (1 - Random) \times C_j, Random \leq 0.50\ ST \tag{38}$$

$$Dm_{i,j} = Tr_{i,j} + k\left(C_j - Random\ tr_{i,j} \times Tr_{i,j}\right) \times \left(Sin\left(\pi \times acos\left(Random\ tr_{i,j}\right)\right)\right), 0.50ST \leq random \leq ST \tag{39}$$

$$Dm_{i,j} = Random\ tr_{i,j} \times Tr_{i,j} + k\left(Tr_{i,j} - Random\ tr_{i,j} \times Tr_{i,j}\right) \times \left(Sin\left(\pi \times acos\left(Random\ tr_{i,j}\right)\right)\right)\ random \geq ST \tag{40}$$

a. Start

b. Number of population is set by,

$$Number\ of\ seeds = Lower\ bound + |(Higher\ bound - Lower\ bound) \times Cos(GTheatv)| + 1.0$$

c. Then "K" expansion coefficient is set by,

$$k = 2.0 \times (1 - Ratio\ \text{function evaluation})$$

d. Value of the parameter ST has been set

e. Problem dimensionality defined

f. End criterion of the process is defined

g. Tree locations or positions engendered arbitrarily by,

$$Trd_{i,j} = Lower\ bound_{j,min} + Random_{i,j} \times \left(Higher\ bound_{j,max} - Lower\ bound_{j,min}\right)$$

h. With respect to the objective function of the problem location or position of the Tree evaluated

i. Most excellent solution will be chosen

$$C = minimum\left(f\left(\overrightarrow{Tr_i}\right)\right)$$

j. Explore with seeds of the Tree

k. For all Trees

l. For every Tree how many seeds to be produced will be defined

m. For all Seeds

n. For all Dimensions

o. $If\ random < 0.50 \times ST$

p. Modernize the seeds by

$$Dm_{i,j} = Random \times Tr_{i,j} + (1 - Random) \times C_j, Random \leq 0.50\ ST$$

q. Else if $(0.50 \times ST \leq random < ST)$

r. Then Modernize the seeds by

$$Dm_{i,j} = Tr_{i,j} + k\left(C_j - Random\ tr_{i,j} \times Tr_{i,j}\right) \times \left(Sin\left(\pi \times acos\left(Random\ tr_{i,j}\right)\right)\right), 0.50ST \leq random \leq ST$$

```
s.   Or else Modernize the seeds by
t.   $Dm_{i,j} =$
     $Random\ tr_{i,j} \times Tr_{i,j} + k\left(Tr_{i,j} - Random\ tr_{i,j} \times Tr_{i,j}\right) \times \left(Sin\left(\pi \times acos\left(Random\ tr_{i,j}\right)\right)\right)\ random \geq ST$
u.   End if
v.   End for
w.   Most excellent seed chosen and it compared with Tree
x.   If the objective value of the seed is better then it will substitute the Tree
y.   End for
z.   Form the population choose the most excellent population by,
     $Maximum\ function\ evaluation = Dimensionality \times 10000$
aa.  When the new most excellent solution is better than preceding solution then it will be replaced
bb.  If the end criterion met then stop the process Or else go to step "j"
cc.  Output the most excellent solution
dd.  End
```

4. Simulation Results

Projected Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been tested in standard IEEE 30 bus system [49]. Active and reactive power consumption is 2.834 and 1.262 per unit on 100 MVA base. Table 1 and Table 2 show the variable parameters. Then comparisons of values are given in Tables 3 to 6. Power loss comparison has been achieved, voltage stability enhancement with voltage deviation minimization attained.

Table 1. Control variables

System [49]	Variables	Minimum (PU)	Maximum (PU)
IEEE 30 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	0.9	1.1
	VAR Source	0	5 (MVAR)

Table 2. System parameters

Description [49]	IEEE 30 bus
NB– number of buses	30
NG- number of generators	6
NT- number of transformers	4
NQ- number of shunt	9
NE- number of branches	41
PLoss (base case) MW	5.66
Base care for VD (PU)	0.58217

Table 3. Comparison of real power loss

	DE [50]	GSA[51]	APOPSO [52]	HTS
Gen.Volt1	1.1	1.071	1.100	1.093
Gen.Volt2	1.09	1.022	1.084	1.041
Gen.Volt5	1.07	1.040	1.056	1.020
Gen.Volt8	1.07	1.051	1.076	1.032
Gen.Volt11	1.1	0.977	1.091	1.090
Gen.Volt13	5	0.968	1.100	0.981

Capacitor Reactive Power 10	5	1.653	5.000	4.980
Capacitor Reactive Power 12	5	4.3722	5.000	5.001
Capacitor Reactive Power 15	5	0.1199	4.879	4.792
Capacitor Reactive Power 17	5	2.0876	4.976	4.980
Capacitor Reactive Power 20	4.41	0.357	3.821	3.710
Capacitor Reactive Power 21	5	0.2602	4.541	4.659
Capacitor Reactive Power 23	2.8004	0.0000	2.354	2.407
Capacitor Reactive Power 24	5	1.3839	4.654	4.509
Capacitor Reactive Power 29	2.5979	0.0000	2.175	2.159
T11 (6-9)	1.04	1.0985	1.029	1.009
T12 (6-10)	0.9097	0.9824	0.911	0.901
T15 (4-12)	0.98	1.095	0.952	0.922
T36 (28-27)	0.9689	1.0593	0.958	0.939
PLoss (MW)	4.555	4.5143	4.398	4.220
VD (PU)	1.9589	0.87522	1.047	1.028
L-index (PU)	0.5513	0.14109	0.1267	0.1224

Table 4. Comparison of different algorithms

	DE [50]	GSA [51]	APOPSO [52]	HTS
Gen.Volt1	1.01	0.983	1.011	1.019
Gen.Volt2	0.99	1.044	1.001	1.016
Gen.Volt5	1.02	1.020	1.014	1.020
Gen.Volt8	1.02	0.999	1.009	1.021
Gen.Volt11	1.01	1.077	0.954	0.943
Gen.Volt13	1.03	1.044	1.000	1.001
Capacitor Reactive Power 10	4.94	0	4.102	4.102
Capacitor Reactive Power 12	1.0885	0.4735	2.124	2.119
Capacitor Reactive Power 15	4.9985	5	4.512	4.492
Capacitor Reactive Power 17	0.2393	0	0.000	0.000
Capacitor Reactive Power 20	4.99	5	5.000	5.000
Capacitor Reactive Power 21	4.90	0	5.000	5.000
Capacitor Reactive Power 23	4.9863	4.9998	5.000	5.000
Capacitor Reactive Power 24	4.9663	5	5.000	5.000
Capacitor Reactive Power 29	2.2325	5	4.120	4.131
T11 (6-9)	1.02	0.9	0.998	0.991
T12 (6-10)	0.9038	1.1	0.822	0.813
T15 (4-12)	1.01	1.051	0.954	0.939
T36 (28-27)	0.9635	0.9619	0.958	0.942
PLoss (MW)	6.4755	6.9117	5.698	5.398
VD (PU)	0.0911	0.0676	0.087	0.069
L-index (PU)	0.14352	0.1349	0.1377	0.1335

Table 5. Comparison of values

	Methods			
	DE [50]	GSA [51]	APOPSO [52]	HTS
Gen.Volt1	1.09	1.1	1.043	1.030
Gen.Volt2	1.09	1.1	1.061	1.049
Gen.Volt5	1.09	1.1	1.061	1.048
Gen.Volt8	1.04	1.1	1.057	1.039
Gen.Volt11	1.09	1.1	1.048	1.040
Gen.Volt13	0.95	1.1	1.091	1.069
Capacitor Reactive Power 10	0.69	5	0.040	0.041
Capacitor Reactive Power 12	4.7163	5	0.039	0.040
Capacitor Reactive Power 15	4.4931	5	0.038	0.042
Capacitor Reactive Power 17	4.51	5	0.040	0.041
Capacitor Reactive Power 20	4.48	5	0.037	0.037
Capacitor Reactive Power 21	4.60	5	0.009	0.019
Capacitor Reactive Power 23	3.8806	5	0.019	0.016
Capacitor Reactive Power 24	3.8806	5	0.011	0.020
Capacitor Reactive Power 29	3.2541	5	0.001	0.007
T11 (6-9)	0.90	0.9	0.919	0.909
T12 (6-10)	0.9029	0.9	0.924	0.912
T15 (4-12)	0.90	0.9	0.938	0.921
T36 (28-27)	0.936	1.0195	0.924	0.922
PLoss (MW)	7.0733	4.9752	4.478	4.219
VD (PU)	1.419	0.21579	1.8579	1.8199
L-index (PU)	0.1246	0.13684	0.1227	0.1192

Table 6. Comparison of loss

	Methods	
	APOPSO [52]	HTS
Gen.Volt1	1.020	1.014
Gen.Volt2	1.033	1.021
Gen.Volt5	1.000	1.000
Gen.Volt8	1.004	1.000
Gen.Volt11	1.032	1.019
Gen.Volt13	1.028	1.022
Capacitor Reactive Power 10	0.051	0.039
Capacitor Reactive Power 12	0.002	0.002
Capacitor Reactive Power 15	0.044	0.039
Capacitor Reactive Power 17	0.009	0.003
Capacitor Reactive Power 20	0.048	0.027
Capacitor Reactive Power 21	0.041	0.038

Capacitor Reactive Power 23	0.033	0.030
Capacitor Reactive Power 24	0.050	0.038
Capacitor Reactive Power 29	0.015	0.019
T11 (6-9)	1.042	1.037
T12 (6-10)	0.909	0.919
T15 (4-12)	1.023	1.015
T36 (28-27)	0.958	0.936
PLoss (MW)	4.842	4.729
VD (PU)	1.009	1.004
L-index (PU)	0.1192	0.1197

Then in standard IEEE 14 bus system, the validity of the proposed Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been evaluated without considering voltage stability index. Table 7 shows the comparison results. Power loss reduced and Percentage of power loss increased by 15.80%

Table 7. Simulation results of IEEE-14 system

Control variables	Base case	MPSO [56]	PSO [55]	EP [54]	SARGA [54]	HTS
Gen.volt−1	1.060	1.100	1.100	NR*	NR*	1.021
Gen.volt−2	1.045	1.085	1.086	1.029	1.060	1.019
Gen.volt−3	1.010	1.055	1.056	1.016	1.036	1.029
Gen.volt−6	1.070	1.069	1.067	1.097	1.099	1.023
Gen.volt−8	1.090	1.074	1.060	1.053	1.078	1.021
Tt 8	0.978	1.018	1.019	1.04	0.95	0.903
Tt 9	0.969	0.975	0.988	0.94	0.95	0.909
Tt 10	0.932	1.024	1.008	1.03	0.96	0.919
capacitor reactive power−9	0.19	14.64	0.185	0.18	0.06	0.142
PG	272.39	271.32	271.32	NR*	NR*	271.31
QG (Mvar)	82.44	75.79	76.79	NR*	NR*	74.40
Reduction in PLoss (%)	0	9.2	9.1	1.5	2.5	15.80
Total PLoss (Mw)	13.550	12.293	12.315	13.346	13.216	11.409

NR* - Not reported.

Then, the proposed Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been tested without considering voltage stability index, in IEEE 30 Bus system. Comparison results are presented in Table 8. Power loss reduction percentage value is 20.74%.

Table 8. Simulation results of IEEE-30 system

Control variables	Base case	MPSO [56]	PSO [55]	EP [54]	SARGA [54]	HTS
Gen.Volt−1	1.060	1.101	1.100	Nr*	Nr*	1.019
Gen.Volt−2	1.045	1.086	1.072	1.097	1.094	1.020
Gen.Volt−5	1.010	1.047	1.038	1.049	1.053	1.039
Gen.Volt−8	1.010	1.057	1.048	1.033	1.059	1.028
Gen.Volt−12	1.082	1.048	1.058	1.092	1.099	1.049
Gen.Volt-13	1.071	1.068	1.080	1.091	1.099	1.043

Tt11	0.978	0.983	0.987	1.01	0.99	0.921
Tt12	0.969	1.023	1.015	1.03	1.03	0.920
Tt15	0.932	1.020	1.020	1.07	0.98	0.911
Tt36	0.968	0.988	1.012	0.99	0.96	0.910
Capacitor Reactive Power10	0.19	0.077	0.077	0.19	0.19	0.094
Capacitor Reactive Power24	0.043	0.119	0.128	0.04	0.04	0.113
PG (MW)	300.9	299.54	299.54	NR*	NR*	298.41
QG (Mvar)	133.9	130.83	130.94	NR*	NR*	130.32
Reduction in PLoss (%)	0	8.4	7.4	6.6	8.3	20.74
Total PLoss (Mw)	17.55	16.07	16.25	16.38	16.09	13.91

NR* - Not reported.

Then the proposed Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been tested without considering voltage stability index in IEEE 57 Bus system. Table 9 shows the comparison results and with reference to base case value percentage of loss reduction is 26.29%.

Table 9. Simulation results of IEEE-57 system

Control variables	Base case	MPSO [56]	PSO [55]	CGA [53]	AGA [53]	HTS
Gen.volt 1	1.040	1.093	1.083	0.968	1.027	1.019
Gen.volt 2	1.010	1.086	1.071	1.049	1.011	1.020
Gen.volt 3	0.985	1.056	1.055	1.056	1.033	1.021
Gen.volt 6	0.980	1.038	1.036	0.987	1.001	1.020
Gen.volt 8	1.005	1.066	1.059	1.022	1.051	1.023
Gen.volt 9	0.980	1.054	1.048	0.991	1.051	1.019
Gen.volt 12	1.015	1.054	1.046	1.004	1.057	1.039
Tt 19	0.970	0.975	0.987	0.920	1.030	0.951
Tt 20	0.978	0.982	0.983	0.920	1.020	0.932
Tt 31	1.043	0.975	0.981	0.970	1.060	0.929
Tt 35	1.000	1.025	1.003	NR*	NR*	1.028
Tt 36	1.000	1.002	0.985	NR*	NR*	1.006
Tt 37	1.043	1.007	1.009	0.900	0.990	1.005
Tt 41	0.967	0.994	1.007	0.910	1.100	0.993
Tt 46	0.975	1.013	1.018	1.100	0.980	1.016
Tt 54	0.955	0.988	0.986	0.940	1.010	0.977
Tt 58	0.955	0.979	0.992	0.950	1.080	0.969
Tt 59	0.900	0.983	0.990	1.030	0.940	0.952
Tt 65	0.930	1.015	0.997	1.090	0.950	1.004
Tt 66	0.895	0.975	0.984	0.900	1.050	0.955
Tt 71	0.958	1.020	0.990	0.900	0.950	1.004
Tt 73	0.958	1.001	0.988	1.000	1.010	1.009
Tt 76	0.980	0.979	0.980	0.960	0.940	0.953
Tt 80	0.940	1.002	1.017	1.000	1.000	1.001

capacitor reactive power 18	0.1	0.179	0.131	0.084	0.016	0.172
capacitor reactive power 25	0.059	0.176	0.144	0.008	0.015	0.159
capacitor reactive power 53	0.063	0.141	0.162	0.053	0.038	0.144
PG (MW)	1278.6	1274.4	1274.8	1276	1275	1267.39
QG (Mvar)	321.08	272.27	276.58	309.1	304.4	271.14
Reduction in PLoss (%)	0	15.4	14.1	9.2	11.6	26.29
Total PLoss (Mw)	27.8	23.51	23.86	25.24	24.56	20.49

NR* - Not reported.

Then the proposed Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been tested without considering voltage stability index in IEEE 118 Bus system. Comparison results are presented in Table 10. Power loss reduction percentage is 14.55%.

Table 10. Simulation results of IEEE-118 system

Control variables	Base case	MPSO [56]	PSO [55]	IPSO [55]	CLPSO [53]	HTS
Gen.volt 1	0.955	1.021	1.019	1.085	1.033	1.013
Gen.volt 4	0.998	1.044	1.038	1.042	1.055	1.042
Gen.volt 6	0.990	1.044	1.044	1.080	0.975	1.030
Gen.volt 8	1.015	1.063	1.039	0.968	0.966	1.004
Gen.volt 10	1.050	1.084	1.040	1.075	0.981	1.029
Gen.volt 12	0.990	1.032	1.029	1.022	1.009	1.028
Gen.volt 15	0.970	1.024	1.020	1.078	0.978	1.039
Gen.volt 18	0.973	1.042	1.016	1.049	1.079	1.033
Gen.volt 19	0.962	1.031	1.015	1.077	1.080	1.030
Gen.volt 24	0.992	1.058	1.033	1.082	1.028	1.029
Gen.volt 25	1.050	1.064	1.059	0.956	1.030	1.031
Gen.volt 26	1.015	1.033	1.049	1.080	0.987	1.037
Gen.volt 27	0.968	1.020	1.021	1.087	1.015	0.901
Gen.volt31	0.967	1.023	1.012	0.960	0.961	0.903
Gen.volt 32	0.963	1.023	1.018	1.100	0.985	0.904
Gen.volt 34	0.984	1.034	1.023	0.961	1.015	1.001
Gen.volt 36	0.980	1.035	1.014	1.036	1.084	1.003
Gen.volt 40	0.970	1.016	1.015	1.091	0.983	0.959
Gen.volt 42	0.985	1.019	1.015	0.970	1.051	1.003
Gen.volt 46	1.005	1.010	1.017	1.039	0.975	1.009
Gen.volt 49	1.025	1.045	1.030	1.083	0.983	1.002
Gen.volt 54	0.955	1.029	1.020	0.976	0.963	0.919
Gen.volt 55	0.952	1.031	1.017	1.010	0.971	0.959
Gen.volt56	0.954	1.029	1.018	0.953	1.025	0.950
Gen.volt 59	0.985	1.052	1.042	0.967	1.000	0.959
Gen.volt 61	0.995	1.042	1.029	1.093	1.077	0.968
Gen.volt 62	0.998	1.029	1.029	1.097	1.048	0.979

Gen.volt 65	1.005	1.054	1.042	1.089	0.968	1.002
Gen.volt 66	1.050	1.056	1.054	1.086	0.964	1.000
Gen.volt 69	1.035	1.072	1.058	0.966	0.957	1.031
Gen.volt 70	0.984	1.040	1.031	1.078	0.976	1.030
Gen.volt 72	0.980	1.039	1.039	0.950	1.024	1.031
Gen.volt 73	0.991	1.028	1.015	0.972	0.965	1.027
Gen.volt 74	0.958	1.032	1.029	0.971	1.073	1.029
Gen.volt 76	0.943	1.005	1.021	0.960	1.030	1.027
Gen.volt 77	1.006	1.038	1.026	1.078	1.027	1.029
Gen.volt 80	1.040	1.049	1.038	1.078	0.985	1.032
Gen.volt 85	0.985	1.024	1.024	0.956	0.983	1.021
Gen.volt 87	1.015	1.019	1.022	0.964	1.088	1.023
Gen.volt 89	1.000	1.074	1.061	0.974	0.989	1.039
Gen.volt 90	1.005	1.045	1.032	1.024	0.990	1.037
Gen.volt 91	0.980	1.052	1.033	0.961	1.028	1.004
Gen.volt 92	0.990	1.058	1.038	0.956	0.976	1.031
Gen.volt 99	1.010	1.023	1.037	0.954	1.088	1.029
Gen.volt 100	1.017	1.049	1.037	0.958	0.961	1.033
Gen.volt 103	1.010	1.045	1.031	1.016	0.961	1.029
Gen.volt 104	0.971	1.035	1.031	1.099	1.012	1.004
Gen.volt 105	0.965	1.043	1.029	0.969	1.068	1.039
Gen.volt 107	0.952	1.023	1.008	0.965	0.976	1.032
Gen.volt 110	0.973	1.032	1.028	1.087	1.041	1.014
Gen.volt 111	0.980	1.035	1.039	1.037	0.979	1.011
Gen.volt 112	0.975	1.018	1.019	1.092	0.976	1.092
Gen.volt 113	0.993	1.043	1.027	1.075	0.972	1.004
Gen.volt 116	1.005	1.011	1.031	0.959	1.033	1.004
Tt 8	0.985	0.999	0.994	1.011	1.004	0.929
Tt 32	0.960	1.017	1.013	1.090	1.060	1.003
Tt 36	0.960	0.994	0.997	1.003	1.000	0.939
Tt 51	0.935	0.998	1.000	1.000	1.000	0.940
Tt 93	0.960	1.000	0.997	1.008	0.992	1.012
Tt 95	0.985	0.995	1.020	1.032	1.007	0.963
Tt 102	0.935	1.024	1.004	0.944	1.061	1.024
Tt 107	0.935	0.989	1.008	0.906	0.930	0.926
Tt 127	0.935	1.010	1.009	0.967	0.957	1.015
capacitor reactive power 34	0.140	0.049	0.048	0.093	0.117	0.033
capacitor reactive power 44	0.100	0.026	0.026	0.093	0.098	0.013
capacitor reactive power 45	0.100	0.196	0.197	0.086	0.094	0.159
capacitor reactive power 46	0.100	0.117	0.118	0.089	0.026	0.140

capacitor reactive power 48	0.150	0.056	0.056	0.118	0.028	0.038
capacitor reactive power 74	0.120	0.120	0.120	0.046	0.005	0.139
capacitor reactive power 79	0.200	0.139	0.140	0.105	0. 148	0.109
capacitor reactive power 82	0.200	0.180	0.180	0.164	0.194	0.149
capacitor reactive power 83	0.100	0.166	0.166	0.096	0.069	0.139
capacitor reactive power 105	0.200	0.189	0.190	0.089	0.090	0.143
capacitor reactive power 107	0.060	0.128	0.129	0.050	0.049	0.133
capacitor reactive power 110	0.060	0.014	0.014	0.055	0.022	0.010
PG (MW)	4374.8	4359.3	4361.4	NR*	NR*	4381.12
QG (MVAR)	795.6	604.3	653.5	* NR*	NR*	612.23
Reduction in PLOSS (%)	0	11.7	10.1	0.6	1.3	14.55
Total PLOSS (Mw)	132.8	117.19	119.34	131.99	130.96	113.47

NR* - Not reported.

Then IEEE 300 bus system is used as test system to validate the performance of the Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been tested without considering voltage stability index. Table 11 shows the comparison of real power loss obtained after optimization.

Table 11. Comparison of Real Power Loss

	EGA [58]	EEA [58]	CSA [57]	HTS
PLOSS (MW)	646.2998	650.6027	635.8942	611.7902

5. Conclusion and future scope of work

Real power Loss has been achieved by proposed Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS). In Tree-seed algorithm, a converse correlation has been maintained between the exploration and exploitation. In search of the optimal values of the dispersion of seeds, it is very fundamental and number of seeds updating will start from maximum and it will be regularly reduced. Then in this work, a new linear parameter "K" has been implemented and it inspired from sine cosine algorithm which induces the solution to jump out from local environment. At first in the procedure, exploration has been improved then gradually exploitation will be enhanced. In proposed work throughout the iterative procedure both the exploration and exploitation has been balanced. In IEEE 30, bus system proposed HTS algorithm has been evaluated. Then the Proposed Hybridization of Tree-seed algorithm with sine-cosine algorithm (HTS) has been tested in standard IEEE 14, 30, 57, 118, 300 bus test systems without considering the voltage stability index. Power loss reduction achieved along with voltage stability enhancement. Mainly voltage deviation minimization also attained. In future, this work can be extended by applying the hybrid algorithm to solve the problem in real time mode. Practical systems can be analyzed and evaluated by the proposed approach.

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