International Journal of Informatics and Communication Technology (IJ-ICT)
Vol.9, No.1, April 2020, pp. 1~8
ISSN: 2252-8776, DOI: 10.11591/ijict.v9i1.pp1-8

Enhanced wormhole optimizer algorithm for solving optimal reactive power problem

Kanagasabai Lenin
Department of EEE, Prasad V. Potluri Siddhartha Institute of Technology, India

Article Info

Article history:

Received Nov 11, 2019
Revised Nov 13, 2019
Accepted Dec 27, 2019

Keywords:

Enhanced wormhole optimizer
Optimal reactive power
Transmission loss

ABSTRACT

In this paper Enhanced Wormhole Optimizer (EWO) algorithm is used to solve optimal reactive power problem. Proposed algorithm based on the Wormholes which exploits the exploration space. Between different universes objects are exchanged through white or black hole tunnels. Regardless of the inflation rate, through wormholes objects in all universes which possess high probability will shift to the most excellent universe. In the projected Enhanced Wormhole Optimizer (EWO) algorithm in order to avoid the solution to be get trapped into the local optimal solution Levy flight has been applied. Projected Enhanced Wormhole Optimizer (EWO) algorithm has been tested in standard IEEE 14, 30, 57,118,300 bus test systems and simulation results show that the EWO algorithm reduced the real power loss efficiently.

Corresponding Author:

Kanagasabai Lenin,
Department of EEE,
Prasad V. Potluri Siddhartha, Institute of Technology,
Kanuru, Vijayawada, Andhra Pradesh -520007, India.
Email: gklenin@gmail.com

1. INTRODUCTION

For secure and economic operations of power system optimal reactive power problem plays vital role. Several types of techniques [1-6] have been utilized to solve the problem previously. Conversely many difficulties are found while solving problem due to inequality constraints. Evolutionary techniques [7-15] are applied to solve the reactive power problem. This paper proposes Enhanced Wormhole Optimizer (EWO) algorithm for solving optimal reactive power problem. Wormhole Optimizer Algorithm is based on the Wormholes which exploit the exploration space. Wormhole tunnel are built for local change in each universe m through most excellent universe then probability of refinement the inflation rate is done through wormholes. Objects are exchanged through tunnels and wormholes objects which possess high probability will shift to the most excellent universe. In the projected Enhanced Wormhole Optimizer (EWO) algorithm in order to avoid the solution to be get trapped into the local optimal solution Levy flight has applied. Projected Enhanced Wormhole Optimizer (EWO) algorithm has been tested in standard IEEE 14, 30, 57,118,300 bus test systems and simulation results show that the projected algorithm reduced the real power loss effectively.

2. PROBLEM FORMULATION

Objective of the problem is to reduce the true power loss:

$$F = P_L = \sum_{k\in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j\cos\theta_{ij}\right) \tag{1}$$

Voltage deviation given as follows:

$$F = P_L + \omega_v \times \text{Voltage Deviation} \quad (2)$$

$$\text{Voltage Deviation} \quad = \sum_{i=1}^{Npq} |V_i - 1| \quad (3)$$

Constraint (Equality)

$$P_G = P_D + P_L \quad (4)$$

Constraints (Inequality)

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \quad (5)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \quad (6)$$

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \quad (7)$$

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \quad (8)$$

$$Q_c^{min} \leq Q_c \leq Q_C^{max}, i \in N_C \quad (9)$$

3. Enhanced Wormhole Optimizer Algorithm

Wormhole Optimizer Algorithm is based on the Wormholes which exploit the exploration space. Through wormholes objects which has high probability will shift to the most excellent universe and it modeled by using roulette wheel selection methodology as follows,

$$U = \begin{bmatrix} y_{11} & \cdots & y_{1d} \\ \vdots & \ddots & \vdots \\ y_{n1} & \cdots & y_{nd} \end{bmatrix} \quad (10)$$

Number of the variables is indicated by “d” and number of universe which is considered as candidate solution is indicated by”n”.

$$y_{ij} = \begin{cases} y_{kj} & random_1 < NI(U_i) \\ y_{ij} & random_1 < NI(U_i) \end{cases} \quad (11)$$

Through roulette wheel selection y_{ij} *'s* “j”th parameter of the “k”th universe will be chosen, in the “i”th universe “j”th parameter is expressed by y_{kj} , ith universe inflation rate indicated by $NI(U_i)$, ith universe indicated by U_i , $random_1 \in [0,1]$.

In between two universes wormhole tunnel [16 ,17] are built then the local change for each universe is done by most excellent universe and the elevated probability of refinement the inflation rate through wormholes is done by,

$$y_{ij} = \begin{cases} \begin{cases} Y_j + Tr.distance\ rate \times \left((ub_j - lb_j) \times rand_4 + lb_j\right) & rand_3 < 0.5 \\ Y_j - Tr.distance\ rate \times \left((ub_j - lb_j) \times rand_4 + lb_j\right) & rand_3 \geq 0.5 \end{cases} & rand_2 < w\ e\ p \\ y_{ij} \quad rand_2 \geq w\ e\ p \end{cases} \quad (12)$$

Wormhole existence probability indicated by “w e p”, “tr.” Indicates the travelling and random denoted by “ rand”.

During the optimization procedure exploitation has been enhanced as follows,

$$\text{Wormhole existence probability} = w_{minimum+}\text{current iteration}\left(\frac{w_{maximum} - w_{minimum}}{\text{maximum iteration}}\right) \quad (13)$$

In order to improve the local search precisely travelling distance rate will be increased over the iterations as follows,

$$Travelling\ distance\ rate = 1 - \frac{\text{current iteration}^{1/p}}{\text{maximum iteration}^{1/p}} \tag{14}$$

In the projected Enhanced Wormhole Optimizer (EWO) algorithm in order to avoid the solution to be get trapped into the local optimal solution Levy flight has been applied.
Levy flight is a rank of non-Gaussian random procedure whose capricious walks are haggard from Levy stable distribution. Allocation by $L(s) \sim |s|^{-1-\beta}$ where $0 < ß < 2$ is an index. Scientifically defined as,

$$L(s,\gamma,\mu) = \begin{cases} \sqrt{\frac{\gamma}{2\pi}} & exp\left[-\frac{\gamma}{2(s-\mu)}\right]\frac{1}{(s-\mu)^{3/2}} \quad if\ 0 < \mu < s < \infty \\ 0 \quad if\ s \leq 0 \end{cases} \tag{15}$$

In terms of Fourier transform Levy distribution defined as

$$F(k) = exp\left[-\alpha|k|^{\beta}\right], 0 < \beta \leq 2, \tag{16}$$

Fresh state is calculated as,

$$Y^{t+1} = Y^t + \alpha \oplus Levy\ (\beta) \tag{17}$$

$$Y^{t+1} = y^t + random\ \left(size(D)\right) \oplus Levy(\beta) \tag{18}$$

In the projected Enhanced Wormhole Optimizer (EWO) algorithm while generation of new solutions U_i^{t+1} levy flight (y) will be applied,

$$U_i^{t+1} = U_i^t + K(lb + (ub - lb) * levy(y)) \times U_i^t \tag{19}$$

Levy flight will be applied in the adaptive mode to balance the exploration and exploitation by applying large levy weight initially and final course the weight of the levy will be decreased,

$$K = \left(\frac{Maximum\ iteration - current\ iteration}{maximum\ iteration}\right) \tag{20}$$

By using Mantegna's algorithm Non-trivial scheme of engendering step size by,

$$s = \frac{u}{|v|^{\frac{1}{\beta}}} \tag{21}$$

$$Y^{t+1} = Y^t + random\ \left(size(D)\right) \oplus Levy(\beta) \sim 0.01\frac{u}{|v|^{1/\beta}}\left(y_j^t - gb\right) \tag{22}$$

$$u \sim N(0,\sigma_u^2) \quad v \sim N(0,\sigma_v^2) \tag{23}$$

with

$$\sigma_u = \left\{\frac{\Gamma(1+\beta)sin(\pi\beta/2)}{\Gamma[(1+\beta)/2]\beta 2^{(\beta-1)/2}}\right\}^{1/\beta}, \sigma_v = 1 \tag{24}$$

then,

$$Levy(y) = 0.01 \times \frac{u \times \sigma}{|v|^{\frac{1}{\beta}}} \tag{25}$$

Start
In put ; “d” & “n” ; Lower bound = $[Lb_1, Lb_2, . . ., L_{bd}]$; Upper bound = $[Ub_1, Ub_2, . . ., U_{bd}]$; Maximum number of iterations
Output: Optimal solution
Step a: Initialization of parameters

Engender arbitrary universes "U" by $UP = \{U_1, U_2, .. U_i, .., U_n\}$
Initialize Wormhole existence probability, travelling distance rate, objective function
t = 0
Step b: categorization and reorganize; arrange the universes; universe inflation rate (UI) will be reorganized
Step c: Iteration; while t < Maximum iteration
Compute universe inflation rate; UI (U_i^t) ; i = 1,2,. . .,n
For every universe "U_i"; modernize Wormhole existence probability, travelling distance rate by
$\text{Wormhole existence probability} = \text{w}_{\text{minimum}+}\text{current iteration}\left(\frac{\text{w}_{\text{maximum}}-\text{w}_{\text{minimum}}}{\text{maximum iteration}}\right)$
$Travelling\ distance\ rate = 1 - \frac{\text{current iteration}^{1/p}}{\text{maximum iteration}^{1/p}}$; Black hole index value = i
Modernize the value "U" by $U_i^{t+1} = U_i^t + K(lb + (ub - lb) * levy(y)) \times U_i^t$
For every object y_{ij} ; $random_1$ = random (0,1);
If $random_1$ < UI(U_i) ; white hole index = roulette wheel selection (-UI);
U (black hole index ,j) = SU(white hole index ,j);
End if
$random_2$= random (0,1);
If $random_2$ < Wormhole existence probability
$random_3$= random (0,1); $random_4$ = random (0,1);
If $random_3$ < 0.5
$y_{ij} = optimal\ solution\ (j) + Travelling\ distance\ rate\ * \left((ub(j) - lb(j)) * random_4 + lb(j)\right)$
Or else
$y_{ij} = optimal\ solution\ (j) - Travelling\ distance\ rate\ * \left((ub(j) - lb(j)) * random_4 + lb(j)\right)$
End if
End for
t = t+1
End while
Step d: End; output the optimal solution

4. SIMULATION RESULTS

At first in standard IEEE 14 bus system [18] the validity of the proposed Enhanced Wormhole Optimizer (EWO) algorithm has been tested, Table 1 shows the constraints of control variables Table 2 shows the limits of reactive power generators and comparison results are presented in Table 3.

Table 1. Constraints of control variables

System	Variables	Minimum (PU)	Maximum (PU)
IEEE 14 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	o.9	1.1
	VAR Source	0	0.20

Table 2. Constrains of reactive power generators

System	Variables	Q Minimum (PU)	Q Maximum (PU)
IEEE 14 Bus	1	0	10
	2	-40	50
	3	0	40
	6	-6	24
	8	-6	24

Table 3. Simulation results of IEEE −14 system

Control variables	Base case	MPSO [19]	PSO [19]	EP [19]	SARGA [19]	EWO
VG−1	1.060	1.100	1.100	NR*	NR*	1.013
VG−2	1.045	1.085	1.086	1.029	1.060	1.014
VG−3	1.010	1.055	1.056	1.016	1.036	1.002
VG−6	1.070	1.069	1.067	1.097	1.099	1.017
VG−8	1.090	1.074	1.060	1.053	1.078	1.021
Tap 8	0.978	1.018	1.019	1.04	0.95	0.910
Tap 9	0.969	0.975	0.988	0.94	0.95	0.913
Tap 10	0.932	1.024	1.008	1.03	0.96	0.927
QC−9	0.19	14.64	0.185	0.18	0.06	0.120
PG	272.39	271.32	271.32	NR*	NR*	271.78
QG (Mvar)	82.44	75.79	76.79	NR*	NR*	75.79
Reduction in PLoss (%)	0	9.2	9.1	1.5	2.5	25.85
Total PLoss (Mw)	13.550	12.293	12.315	13.346	13.216	10.047

NR* - Not reported.

Then Enhanced Wormhole Optimizer (EWO) algorithm has been tested, in IEEE 30 Bus system. Table 4 shows the constraints of control variables, Table 5 shows the limits of reactive power generators and comparison results are presented in Table 6.

Table 4. Constraints of control variables

System	Variables	Minimum (PU)	Maximum (PU)
IEEE 30 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	o.9	1.1
	VAR Source	0	0.20

Table 5. Constrains of reactive power generators

System	Variables	Q Minimum (PU)	Q Maximum (PU)
IEEE 30 Bus	1	0	10
	2	-40	50
	5	-40	40
	8	-10	40
	11	-6	24
	13	-6	24

Table 6. Simulation results of IEEE −30 system

Control variables	Base case	MPSO [19]	PSO [19]	EP [19]	SARGA [19]	EWO
VG −1	1.060	1.101	1.100	NR*	NR*	1.013
VG −2	1.045	1.086	1.072	1.097	1.094	1.014
VG −5	1.010	1.047	1.038	1.049	1.053	1.010
VG −8	1.010	1.057	1.048	1.033	1.059	1.021
VG −12	1.082	1.048	1.058	1.092	1.099	1.032
VG-13	1.071	1.068	1.080	1.091	1.099	1.024
Tap11	0.978	0.983	0.987	1.01	0.99	0.934
Tap12	0.969	1.023	1.015	1.03	1.03	0.930
Tap15	0.932	1.020	1.020	1.07	0.98	0.921
Tap36	0.968	0.988	1.012	0.99	0.96	0.923
QC10	0.19	0.077	0.077	0.19	0.19	0.092
QC24	0.043	0.119	0.128	0.04	0.04	0.124
PG (MW)	300.9	299.54	299.54	NR*	NR*	297.68
QG (Mvar)	133.9	130.83	130.94	NR*	NR*	131.41
Reduction in PLoss (%)	0	8.4	7.4	6.6	8.3	19.37
Total PLoss (Mw)	17.55	16.07	16.25	16.38	16.09	14.149

Then the proposed Enhanced Wormhole Optimizer (EWO) algorithm has been tested, in IEEE 57 Bus system. Table 7 shows the constraints of control variables, Table 8 shows the limits of reactive power generators and comparison results are presented in Table 9.

Table 7. Constraints of control variables

System	Variables	Minimum (PU)	Maximum (PU)
IEEE 57 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	o.9	1.1
	VAR Source	0	0.20

Table 8. Constrains of reactive power generators

System	Variables	Q Minimum (PU)	Q Maximum (PU)
IEEE 57 Bus	1	-140	200
	2	-17	50
	3	-10	60
	6	-8	25
	8	-140	200
	9	-3	9
	12	-150	155

Then the proposed Enhanced Wormhole Optimizer algorithm has been tested, in IEEE 118 Bus system. Table 10 shows the constraints of control variables and comparison results are presented in Table 11.

Table 9. Simulation results of IEEE −57 system

Control variables	Base case	MPSO [19]	PSO [19]	CGA [19]	AGA [19]	EWO
VG 1	1.040	1.093	1.083	0.968	1.027	1.023
VG 2	1.010	1.086	1.071	1.049	1.011	1.010
VG 3	0.985	1.056	1.055	1.056	1.033	1.034
VG 6	0.980	1.038	1.036	0.987	1.001	1.012
VG 8	1.005	1.066	1.059	1.022	1.051	1.030
VG 9	0.980	1.054	1.048	0.991	1.051	1.011
VG 12	1.015	1.054	1.046	1.004	1.057	1.040
Tap 19	0.970	0.975	0.987	0.920	1.030	0.952
Tap 20	0.978	0.982	0.983	0.920	1.020	0.937
Tap 31	1.043	0.975	0.981	0.970	1.060	0.920
Tap 35	1.000	1.025	1.003	NR*	NR*	1.019
Tap 36	1.000	1.002	0.985	NR*	NR*	1.007
Tap 37	1.043	1.007	1.009	0.900	0.990	1.009
Tap 41	0.967	0.994	1.007	0.910	1.100	0.990
Tap 46	0.975	1.013	1.018	1.100	0.980	1.010
Tap 54	0.955	0.988	0.986	0.940	1.010	0.971
Tap 58	0.955	0.979	0.992	0.950	1.080	0.966
Tap 59	0.900	0.983	0.990	1.030	0.940	0.963
Tap 65	0.930	1.015	0.997	1.090	0.950	1.001
Tap 66	0.895	0.975	0.984	0.900	1.050	0.950
Tap 71	0.958	1.020	0.990	0.900	0.950	1.001
Tap 73	0.958	1.001	0.988	1.000	1.010	1.000
Tap 76	0.980	0.979	0.980	0.960	0.940	0.968
Tap 80	0.940	1.002	1.017	1.000	1.000	1.002
QC 18	0.1	0.179	0.131	0.084	0.016	0.174
QC 25	0.059	0.176	0.144	0.008	0.015	0.168
QC 53	0.063	0.141	0.162	0.053	0.038	0.140
PG (MW)	1278.6	1274.4	1274.8	1276	1275	1270.13
QG (Mvar)	321.08	272.27	276.58	309.1	304.4	272.34
Reduction in PLoss (%)	0	15.4	14.1	9.2	11.6	24.07
Total PLoss (Mw)	27.8	23.51	23.86	25.24	24.56	21.108

NR* - Not reported.

Table 10. Constraints of control variables

System	Variables	Minimum (PU)	Maximum (PU)
IEEE 118 Bus	Generator Voltage	0.95	1.1
	Transformer Tap	o.9	1.1
	VAR Source	0	0.20

Table 11. Simulation results of IEEE −118 system

Control variables	Base case	MPSO [19]	PSO [19]	PSO [19]	CLPSO [19]	EWO
VG 1	0.955	1.021	1.019	1.085	1.033	1.010
VG 4	0.998	1.044	1.038	1.042	1.055	1.044
VG 6	0.990	1.044	1.044	1.080	0.975	1.022
VG 8	1.015	1.063	1.039	0.968	0.966	1.003
VG 10	1.050	1.084	1.040	1.075	0.981	1.010
VG 12	0.990	1.032	1.029	1.022	1.009	1.021
VG 15	0.970	1.024	1.020	1.078	0.978	1.030
VG 18	0.973	1.042	1.016	1.049	1.079	1.041
VG 19	0.962	1.031	1.015	1.077	1.080	1.030
VG 24	0.992	1.058	1.033	1.082	1.028	1.014
VG 25	1.050	1.064	1.059	0.956	1.030	1.035
VG 26	1.015	1.033	1.049	1.080	0.987	1.056
VG 27	0.968	1.020	1.021	1.087	1.015	0.909
VG 31	0.967	1.023	1.012	0.960	0.961	0.907
VG 32	0.963	1.023	1.018	1.100	0.985	0.913
VG 34	0.984	1.034	1.023	0.961	1.015	1.001
VG 36	0.980	1.035	1.014	1.036	1.084	1.000
VG 40	0.970	1.016	1.015	1.091	0.983	0.960
VG 42	0.985	1.019	1.015	0.970	1.051	1.001
VG 46	1.005	1.010	1.017	1.039	0.975	1.002
VG 49	1.025	1.045	1.030	1.083	0.983	1.000

Table 11. Simulation results of IEEE −118 system (*Continued*)

Control variables	Base case	MPSO [19]	PSO [19]	PSO [19]	CLPSO [19]	EWO
VG 54	0.955	1.029	1.020	0.976	0.963	0.920
VG 55	0.952	1.031	1.017	1.010	0.971	0.961
VG 56	0.954	1.029	1.018	0.953	1.025	0.950
VG 59	0.985	1.052	1.042	0.967	1.000	0.961
VG 61	0.995	1.042	1.029	1.093	1.077	0.973
VG 62	0.998	1.029	1.029	1.097	1.048	0.984
VG 65	1.005	1.054	1.042	1.089	0.968	1.002
VG 66	1.050	1.056	1.054	1.086	0.964	1.000
VG 69	1.035	1.072	1.058	0.966	0.957	1.051
VG 70	0.984	1.040	1.031	1.078	0.976	1.033
VG 72	0.980	1.039	1.039	0.950	1.024	1.024
VG 73	0.991	1.028	1.015	0.972	0.965	1.013
VG 74	0.958	1.032	1.029	0.971	1.073	1.012
VG 76	0.943	1.005	1.021	0.960	1.030	1.000
VG 77	1.006	1.038	1.026	1.078	1.027	1.004
VG 80	1.040	1.049	1.038	1.078	0.985	1.005
VG 85	0.985	1.024	1.024	0.956	0.983	1.012
VG 87	1.015	1.019	1.022	0.964	1.088	1.013
VG 89	1.000	1.074	1.061	0.974	0.989	1.040
VG 90	1.005	1.045	1.032	1.024	0.990	1.030
VG 91	0.980	1.052	1.033	0.961	1.028	1.002
VG 92	0.990	1.058	1.038	0.956	0.976	1.030
VG 99	1.010	1.023	1.037	0.954	1.088	1.005
VG 100	1.017	1.049	1.037	0.958	0.961	1.001
VG 103	1.010	1.045	1.031	1.016	0.961	1.010
VG 104	0.971	1.035	1.031	1.099	1.012	1.001
VG 105	0.965	1.043	1.029	0.969	1.068	1.050
VG 107	0.952	1.023	1.008	0.965	0.976	1.016
VG 110	0.973	1.032	1.028	1.087	1.041	1.015
VG 111	0.980	1.035	1.039	1.037	0.979	1.007
VG 112	0.975	1.018	1.019	1.092	0.976	1.091
VG 113	0.993	1.043	1.027	1.075	0.972	1.000
VG 116	1.005	1.011	1.031	0.959	1.033	1.006
Tap 8	0.985	0.999	0.994	1.011	1.004	0.942
Tap 32	0.960	1.017	1.013	1.090	1.060	1.004
Tap 36	0.960	0.994	0.997	1.003	1.000	0.956
Tap 51	0.935	0.998	1.000	1.000	1.000	0.930
Tap 93	0.960	1.000	0.997	1.008	0.992	1.001
Tap 95	0.985	0.995	1.020	1.032	1.007	0.972
Tap 102	0.935	1.024	1.004	0.944	1.061	1.004
Tap 107	0.935	0.989	1.008	0.906	0.930	0.942
Tap 127	0.935	1.010	1.009	0.967	0.957	1.001
QC 34	0.140	0.049	0.048	0.093	0.117	0.005
QC 44	0.100	0.026	0.026	0.093	0.098	0.020
QC 45	0.100	0.196	0.197	0.086	0.094	0.161
QC 46	0.100	0.117	0.118	0.089	0.026	0.120
QC 48	0.150	0.056	0.056	0.118	0.028	0.043
QC 74	0.120	0.120	0.120	0.046	0.005	0.110
QC 79	0.200	0.139	0.140	0.105	0. 148	0.105
QC 82	0.200	0.180	0.180	0.164	0.194	0.150
QC 83	0.100	0.166	0.166	0.096	0.069	0.122
QC 105	0.200	0.189	0.190	0.089	0.090	0.150
QC 107	0.060	0.128	0.129	0.050	0.049	0.132
QC 110	0.060	0.014	0.014	0.055	0.022	0.001
PG(MW)	4374.8	4359.3	4361.4	NR*	NR*	4362.02
QG(MVAR)	795.6	604.3	653.5	* NR*	NR*	610.11
Reduction in PLOSS (%)	0	11.7	10.1	0.6	1.3	14.15
Total PLOSS (Mw)	132.8	117.19	119.34	131.99	130.96	114.005

NR* - Not reported.

Then IEEE 300 bus system [18] is used as test system to validate the performance of Enhanced Wormhole Optimizer (EWO) algorithm. Table 12 shows the comparison of real power loss obtained after optimization.

Table 12. Comparison of Real Power Loss

Parameter	Method CSA [20]	Method EGA [21]	Method EEA [21]	EWO
PLOSS (MW)	635.8942	646.2998	650.6027	612.1026

5. CONCLUSION

In this paper proposed Enhanced Wormhole Optimizer (EWO) algorithm successfully solved the optimal reactive power problems. Between different universes objects are exchanged through white or black hole tunnels. Regardless of the inflation rate, through wormholes objects in all universes which possess high probability will shift to the most excellent universe. In between two universes wormhole tunnel are built then the local change for each universe is done by most excellent universe and the elevated probability of refinement the inflation rate through wormholes. Levy flight has been applied effectively and it leads to the improvement of the quality of solution. Proposed Enhanced Wormhole Optimizer (EWO) algorithm has been tested in standard IEEE 14, 30, 57,118,300 bus test systems and simulation results show that the EWO algorithm reduced the real power loss efficiently. Percentage of real power loss reduction has been enhanced when compared to other standard algorithms.

REFERENCES

[1] K. Y. Lee, "Fuel-cost minimisation for both real and reactive-power dispatches," *Proceedings Generation, Transmission and Distribution Conference*, vol. 131, no. 3, pp. 85-93, 1984.

[2] N. I. Deeb, "An efficient technique for reactive power dispatch using a revised linear programming approach," *Electric Power System Research*, vol. 15, no. 2, pp. 121–134, 1998.

[3] M. R. Bjelogrlic, M. S. Calovic, B. S. Babic, "Application of Newton's optimal power flow in voltage/reactive power control," *IEEE Trans Power System*, vol. 5, no. 4, pp. 1447-1454, 1990.

[4] S. Granville, "Optimal reactive dispatch through interior point methods," *IEEE Transactions on Power System*, vol. 9, no. 1, pp. 136–146, 1994.

[5] N. Grudinin, "Reactive power optimization using successive quadratic programming method," *IEEE Transactions on Power System*, vol. 13, no. 4, pp. 1219–1225, 1998.

[6] Ng Shin Mei, R., Sulaiman, M.H., Mustaffa, Z., Daniyal, H., "Optimal reactive power dispatch solution by loss minimization using moth-flame optimization technique," *Appl. Soft Comput.*, vol. 59, pp. 210–222, 2017.

[7] Chen, G., Liu, L., Zhang, Z., Huang, S., "Optimal reactive power dispatch by improved GSA-based algorithm with the novel strategies to handle constraints," Appl. Soft Comput., vol. 50, pp. 58–70, 2017.

[8] Roy, Provas Kumar and Susanta Dutt, "Economic load dispatch: Optimal power flow and optimal reactive power dispatch concept," *Optimal Power Flow Using Evolutionary Algorithms*, IGI Global, pp. 46-64, 2019.

[9] Christian Bingane, Miguel F. Anjos, Sébastien Le Digabel, "Tight-and-cheap conic relaxation for the optimal reactive power dispatch problem," *IEEE Transactions on Power Systems*, vol. 34, no. 6, 2019.

[10] Dharmbir Prasad & Vivekananda Mukherjee, "Solution of Optimal Reactive Power Dispatch by Symbiotic Organism Search Algorithm Incorporating FACTS Devices," *IETE Journal of Research*, vol. 64, no. 1, pp. 149-160, 2018.

[11] TM Aljohani, et al, "Single and multiobjective optimal reactive power dispatch based on hybrid artificial physics–particle swarm optimization," *Energies*, vol. 12, no. 12, p. 2333, 2019

[12] Ram Kishan Mahate, & Himmat Singh, "Multi-Objective Optimal Reactive Power Dispatch Using Differential Evolution," *International Journal of Engineering Technologies and Management Research*, vol. 6, no. 2, pp. 27–38, 2019.

[13] Yalçın, E, Taplamacıoğlu, M., Çam, E., "The Adaptive Chaotic Symbiotic Organisms Search Algorithm Proposal for Optimal Reactive Power Dispatch Problem in Power Systems," *Electrica*, vol. 19, no. 1, pp. 37-47, 2019.

[14] Mouassa, S. and Bouktir, T., "Multi-objective ant lion optimization algorithm to solve large-scale multi-objective optimal reactive power dispatch problem," *COMPEL - The international journal for computation and mathematics in electrical and electronic engineering*, vol. 38, no. 1, pp. 304-324, 2018.

[15] Tawfiq M. Aljohani, Ahmed F. Ebrahim, Osama Mohammed, "Single and multiobjective optimal reactive power dispatch based on hybrid artificial physics–particle swarm optimization," *Energies*, vol. 12, no. 12, pp. 2333, 2019.

[16] Abdechiri M, Meybodi MR and Bahrami H., "Gases Brownian motion optimization: An algorithm for optimization (GBMO)," *Applied Soft Computing*, vol. 13, no. 5, pp. 2932–2946, 2013.

[17] Mirjalili SM and Hatamlou A., "Multi-verse optimizer: A nature-inspired algorithm for global optimization," *Neural Computing and Applications*, vol. 27, no. 2, pp. 495–513, 2016.

[18] IEEE, "The IEEE-test systems," 1993. http://www.ee.washington.edu/trsearch/pstca/.

[19] Ali Nasser Hussain, Ali Abdulabbas Abdullah and Omar Muhammed Neda, "Modified particle swarm optimization for solution of reactive power dispatch," *Research Journal of Applied Sciences, Engineering and Technology*, vol. 15, no. 8, pp. 316-327, 2018.

[20] S. Surender Reddy, "Optimal reactive power scheduling using cuckoo search algorithm," *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 7, no. 5, pp. 2349-2356. 2017.

[21] S.S. Reddy, et al., "Faster evolutionary algorithm based optimal power flow using incremental variables," *Electrical Power and Energy Systems*, vol. 54, pp. 198-210, 2014.