Available online at http://jurnal.ahmar.id/index.php/asci

Journal of Applied Science, Engineering, Technology, and Education

ISSN 2685-0591 (Online)

Journal of Applied Science, Engineering, Technology, and Education Vol. 2 No. 1 (2020)
https://doi.org/10.35877/454RI.asci2166

Real Power Loss Reduction by Amplified Water Cycle Algorithm

Kanagasabai Lenin*

Department of EEE, Prasad V.Potluri Siddhartha Institute of Technology, India, gklenin@gmail.com

Abstract

In this paper Amplified Water Cycle Algorithm (AWCA) has been used to solve the optimal reactive power problem. Water cycle algorithm (WCA) is a methodology which inspired by the hydrological cycle which happen in nature. In this work water cycle algorithm hybridized with Gravitational Search Algorithm**,** Chaos theory. In the projected Amplified Water Cycle Algorithm (AWCA) - with reference to the fitness value, population is first alienated into three groups: streams, rivers and sea. Through this hybridization exploration and exploitation is effectively improved. Positions of particles are initially modernized according to gravitational search. Chaos theory is then defined and integrated in water cycle algorithm to modernize the population which will augment explore capability and population diversity. Projected Amplified Water Cycle Algorithm (AWCA) has been tested in standard IEEE 14, 30, 57, 300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

Keywords: Optimal Reactive Power, Transmission loss, Gravitational Search Algorithm**,** Chaos theory, Water Cycle Algorithm.

1. Introduction

Reactive power problem plays an important role in secure and economic operations of power system. Numerous types of methods [1-6] have been utilized to solve the optimal reactive power problem. However many scientific difficulties are found while solving problem due to an assortment of constraints. Evolutionary techniques [7-14] are applied to solve the reactive power problem, but the main problem is many algorithms get stuck in local optimal solution & failed to balance the Exploration & Exploitation during the search of global solution. In this work Amplified Water Cycle Algorithm (AWCA) has been used to solve the optimal reactive power problem. Water cycle algorithm (WCA) is a methodology which inspired by the hydrological cycle which happen in nature. Hydrologic cycle is unremitting progression of water in the earth. It is a vital process for the continuous survival of ecosystems. In this work water cycle algorithm hybridized with **Gravitational Search Algorithm,** Chaos theory. Positions of particles are initially modernized according to gravitational search. Chaos theory is then defined and integrated in water cycle algorithm to modernize the population which will augment explore capability and population diversity. In the projected Amplified Water Cycle Algorithm (AWCA) - with reference to the fitness value, population is first alienated into three groups: streams, rivers and sea. Through this hybridization exploration and exploitation is effectively improved. Projected Amplified Water Cycle Algorithm (AWCA) has been tested in standard IEEE 14, 30, 57, 300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively.

* Corresponding author.
E-mail address: gklenin@gmail.com (Kanagasabai Lenin)

2. Problem Formulation

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

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

Where F- objective function, P_L – power loss, g_k - conductance of branch, V_i and V_j are voltages at buses i,j, Nbr- total number of transmission lines in power systems.
Voltage deviation given as follows:

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

Where VD - voltage deviation, ω_v- is a weighting factor of voltage deviation
Voltage deviation given by:

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

Where Npq- number of load buses

Constraint (Equality)

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

Where P_G- total power generation, P_D - total power demand.

Constraints (Inequality)

Upper and lower bounds on the active power of slack bus (P_g), and reactive power of generators (Q_g) are written as follows:

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

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

Upper and lower bounds on the bus voltage magnitudes (V_i) are given by:

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

Upper and lower bounds on the transformers tap ratios (T_i) are given by:

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

Upper and lower bounds on the compensators (Q_c) are given by:

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

Where N is the total number of buses, N_g is the total number of generators, N_T is the total number of Transformers, N_c is the total number of shunt reactive compensators.

3. Gravitational Search Algorithm

Gravitational Search Algorithm (GSA is stimulated from is the Newton's theory and it has been considered as collection of agents (determine the candidate solutions) in which mass value is proportional to the value of fitness function [15]. By the gravity forces, all masses are attracting each other during generations. Algorithm starts with arbitrarily insertion of all agents in exploration space. Throughout all time, gravitational forces from agent *j* on agent *i* at a precise time *t* is described by;

$$F_{ij}^{d}(t) = G(t)\frac{M_{pi}(t) \times M_{aj}(t)}{R_{ij}(t)+\epsilon}\left(x_j^d(t) - x_i^d(t)\right) \quad (10)$$

$$G(t) = G_0 \times \exp\left(-a \times \frac{iter}{maxiter}\right) \quad (11)$$

Entire force which act on the agent is calculated by,

$$F_i^d(t) = \sum_{i=1, j\neq i}^{N} rand_j\, F_{ij}^d(t) \quad (12)$$

Acceleration of the agents computed by,

$$ac_i^d(t) = \frac{F_i^d(t)}{M_{ii}(t)} \quad (13)$$

The velocity and position of agents are computed by,

$$vel_i^d(t+1) = rand_i \times vel_i^d(t) + ac_i^d(t) \quad (14)$$

$$x_i^d(t+1) = x_i^d(t) + vel_i^d(t+1) \quad (15)$$

4. Chaos Theory

Chaos is a deterministic, arbitrary like procedure found in a nonlinear, dynamical system, which is non-period, non-converging and non-bounded [16]. Variance σ^2 exhibits the converging degree of the particles.

$$\sigma^2 = \sum_{i=1}^{N}\left[\left(f_i - f_{avg}\right)/f\right]^2 \quad (16)$$

$$f = max\left\{1, max\left\{\left|f_i - f_{avg}\right|\right\}\right\} \quad (17)$$

Simple vibrant system devoid of any stochastic disturbance is formulated by,

$$y_{id}(t+1) = \mu y_{id}(t)\left(1 - y_{id}(t)\right) \quad (18)$$

Once the preliminary value is $y_{id}(0) \in \{0.20.0.5.0.70\}$ then by using equation (18) chaotic sequences can be attained. Adaptive chaotic disturbance P_c is employed at the time of stagnation;

$$p'_{cd}(t+1) = p_{cd}(t) + R_{id}\left(2_{yid}(t) - 1\right) \quad (19)$$

$$R_{id} = \beta\left|p_{cd}(t) - p_{id}(t)\right| \quad (20)$$

5. Amplified Water cycle algorithm

Water cycle algorithm (WCA) starts with presumption of rain. A sea is chosen as the most excellent individual, and a number of value raindrops are picked to indicate a river, remaining raindrops signify the streams flowing into sea and rivers [17].

Array for single solution is aptly described as a "raindrop". Raindrop is an array of $1 \times N_{var}$ in a N_{var} dimensional space and defined as:

$$Raindrop = [X_1, X_2, X_3, \ldots, X_n] \quad (21)$$

Cost of the raindrop is calculated by using the cost function (C) as follows,

$$c_i = cost_i = \int \left(X_1^i, X_2^i, \ldots, X_{N_{var}}^i\right) i = 1,2, \ldots, N_{pop} \quad (22)$$

Where N_{pop} and N_{var} are symbolize the number of raindrops and N_{sr} -Signify the entire number of rivers for a single sea.

$$N_{sr} = number\ os\ rivers + 1 \quad (23)$$

$$N_{raindrops} = N_{pop} - N_{sr} \quad (24)$$

Strength of flow of the raindrops into the sea or the rivers is computed by:

$$NS_n = round \left\{ \left| \frac{cost_n}{\sum_{i=1}^{N_{sr}} cost_i} \right| \times N_{rain\ drops} \right\}, n = 1,2, \ldots, N_{sr} \quad (25)$$

Rivers flow into the sea and the new-fangled position of the rivers and streams can be defined by,

$$X_{stream}^{i+} = X_{stream}^{i} + rand \times c \times \left(X_{River}^{i} - X_{stream}^{i}\right) \quad (26)$$

$$X_{River}^{i+} = X_{River}^{i} + rand \times c \times \left(X_{sea}^{i} - X_{River}^{i}\right) \quad (27)$$

d_{max} symbolize the evaporation process and the value of d_{max} adapts consequently,

$$d_{maximum}^{i+1} = d_{maximum}^{i} - \frac{d_{maximum}^{i}}{maximum\ number\ of\ teration} \quad (28)$$

New-fangled locations of the newly formed streams is defined by,

$$X_{stream}^{new} = LB + random \times (Ub - LB) \quad (29)$$

$$X_{stream}^{new} = X_{sea} + \sqrt{\mu} \times random\ n(1, N_{var}) \quad (30)$$

Where μ is a coefficient that specifies the range of the exploration area close to the sea and random n is the generally distributed arbitrary number.

In the projected Amplified Water Cycle Algorithm (AWCA) - with reference to the fitness value, population is first alienated into three groups: streams, rivers and sea. Location of streams and rivers are then modernized using Equations (14, 15) in GSA correspondingly, where streams and rivers transfer information each other in their own groups, respectively. Next, the rivers and stream are updated by the Eqs. (31), (32) and (33) . Equations are acquire by combining the chaotic sequence create by chaotic mapping.

$$X_{stream}^{t+1} = X_{stream}^{t} + (1 + h_i) \times \left(X_{river}^{i} - \vec{X}_{stream}^{i}\right) \quad (31)$$
$$X_{stream}^{t+1} = X_{stream}^{t} + (1 + h_i) \times \left(X_{sea}^{i} - \vec{X}_{stream}^{i}\right) \quad (32)$$
$$X_{river}^{t+1} = X_{river}^{t} + (1 + h_i) \times \left(X_{sea}^{i} - \vec{X}_{river}^{i}\right) \quad (33)$$

1: Input: parameters values are determined

2: Establish the number of streams which flow to the rivers and sea using $N_{sr} = number\ os\ rivers + 1$; $N_{raindrops} = N_{pop} - N_{sr}$

3: Preliminary populations are created arbitrarily and it form streams, rivers and sea, with reference to the fitness value

4: Compute the concentration of flow about how many stream flow to their corresponding rivers and sea) by using the equation $NS_n = round\left\{\left|\frac{cost_n}{\sum_{i=1}^{N_{sr}} cost_i}\right| \times N_{rain\ drops}\right\}, n = 1,2,\ldots,N_{sr}$

5: While number of function evaluations $\leq$ maximum number of function evaluations do

6: Modernize the position of streams and rivers by using the equations $vel_i^d(t+1) = rand_i \times vel_i^d(t) + ac_i^d(t)$; $x_i^d(t+1) = x_i^d(t) + vel_i^d(t+1)$

7: Engender chaotic sequence and modernize streams flowing to its subsequent rivers and sea by utilizing the equations;
$X_{stream}^{t+1} = X_{stream}^{t} + (1 + h_i) \times \left(X_{river}^{i} - \vec{X}_{stream}^{i}\right)$; $X_{stream}^{t+1} = X_{stream}^{t} + (1 + h_i) \times \left(X_{sea}^{i} - \vec{X}_{stream}^{i}\right)$

8: Compute the fitness value of the engendered stream- when the fitness value of the produced stream is superior than the analogous river and sea, then swap the position of them.

9: Engender chaotic sequence and modernize rivers flowing to the sea by using the equation; $X_{river}^{t+1} = X_{river}^{t} + (1 + h_i) \times \left(X_{sea}^{i} - \vec{X}_{river}^{i}\right)$

10: Compute the fitness value of the engendered river- when the fitness value of the engendered river is superior to the resultant sea, then swap the position of them.

11: When the condition of evaporation process is fulfilled, then perform the raining procedure.

12: Modernize the values of d_{max} and G;

13: End while

14: Output: obtained optimal values

6. Simulation results

At first in standard IEEE 14 bus system [18] the validity of the proposed Amplified Water Cycle Algorithm (AWCA) 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 [21]	PSO [20]	EP [19]	SARGA [19]	AWCA
$VG-1$	1.060	1.100	1.100	NR*	NR*	1.020
$VG-2$	1.045	1.085	1.086	1.029	1.060	1.029
$VG-3$	1.010	1.055	1.056	1.016	1.036	1.022
$VG-6$	1.070	1.069	1.067	1.097	1.099	1.030
$VG-8$	1.090	1.074	1.060	1.053	1.078	1.013
Tap 8	0.978	1.018	1.019	1.04	0.95	0.902
Tap 9	0.969	0.975	0.988	0.94	0.95	0.919
Tap 10	0.932	1.024	1.008	1.03	0.96	0.932
$QC-9$	0.19	14.64	0.185	0.18	0.06	0.149
PG	272.39	271.32	271.32	NR*	NR*	271.60
QG (Mvar)	82.44	75.79	76.79	NR*	NR*	74.79
Reduction in PLoss (%)	0	9.2	9.1	1.5	2.5	23.46
Total PLoss (Mw)	13.550	12.293	12.315	13.346	13.216	10.370

NR* - Not reported.

Then the proposed Amplified Water Cycle Algorithm (AWCA) 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 [21]	PSO [20]	EP [19]	SARGA [19]	AWCA
$VG-1$	1.060	1.101	1.100	NR*	NR*	1.030
$VG-2$	1.045	1.086	1.072	1.097	1.094	1.021
$VG-5$	1.010	1.047	1.038	1.049	1.053	1.044
$VG-8$	1.010	1.057	1.048	1.033	1.059	1.019
$VG-12$	1.082	1.048	1.058	1.092	1.099	1.059
VG-13	1.071	1.068	1.080	1.091	1.099	1.049
Tap11	0.978	0.983	0.987	1.01	0.99	0.909
Tap12	0.969	1.023	1.015	1.03	1.03	0.912
Tap15	0.932	1.020	1.020	1.07	0.98	0.909

Control variables	Base case	MPSO [21]	PSO [20]	EP [19]	SARGA [19]	AWCA
Tap36	0.968	0.988	1.012	0.99	0.96	0.900
QC10	0.19	0.077	0.077	0.19	0.19	0.091
QC24	0.043	0.119	0.128	0.04	0.04	0.119
PG (MW)	300.9	299.54	299.54	NR*	NR*	298.89
QG (Mvar)	133.9	130.83	130.94	NR*	NR*	130.24
Reduction in PLoss (%)	0	8.4	7.4	6.6	8.3	16.80
Total PLoss (Mw)	17.55	16.07	16.25	16.38	16.09	14.60

NR* - Not reported.

Then the proposed Amplified Water Cycle Algorithm (AWCA) 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	0.9	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

Table 9: Simulation results of IEEE −57 system

Control variables	Base case	MPSO [21]	PSO [20]	CGA [19]	AGA [19]	AWCA
VG 1	1.040	1.093	1.083	0.968	1.027	1.021
VG 2	1.010	1.086	1.071	1.049	1.011	1.023
VG 3	0.985	1.056	1.055	1.056	1.033	1.030
VG 6	0.980	1.038	1.036	0.987	1.001	1.022
VG 8	1.005	1.066	1.059	1.022	1.051	1.029
VG 9	0.980	1.054	1.048	0.991	1.051	1.017
VG 12	1.015	1.054	1.046	1.004	1.057	1.039
Tap 19	0.970	0.975	0.987	0.920	1.030	0.947
Tap 20	0.978	0.982	0.983	0.920	1.020	0.930
Tap 31	1.043	0.975	0.981	0.970	1.060	0.931
Tap 35	1.000	1.025	1.003	NR*	NR*	1.017
Tap 36	1.000	1.002	0.985	NR*	NR*	1.002
Tap 37	1.043	1.007	1.009	0.900	0.990	1.001
Tap 41	0.967	0.994	1.007	0.910	1.100	0.992
Tap 46	0.975	1.013	1.018	1.100	0.980	1.014
Tap 54	0.955	0.988	0.986	0.940	1.010	0.969

Control variables	Base case	MPSO [21]	PSO [20]	CGA [19]	AGA [19]	AWCA
Tap 58	0.955	0.979	0.992	0.950	1.080	0.963
Tap 59	0.900	0.983	0.990	1.030	0.940	0.964
Tap 65	0.930	1.015	0.997	1.090	0.950	1.003
Tap 66	0.895	0.975	0.984	0.900	1.050	0.949
Tap 71	0.958	1.020	0.990	0.900	0.950	1.003
Tap 73	0.958	1.001	0.988	1.000	1.010	1.001
Tap 76	0.980	0.979	0.980	0.960	0.940	0.962
Tap 80	0.940	1.002	1.017	1.000	1.000	1.003
QC 18	0.1	0.179	0.131	0.084	0.016	0.165
QC 25	0.059	0.176	0.144	0.008	0.015	0.164
QC 53	0.063	0.141	0.162	0.053	0.038	0.139
PG (MW)	1278.6	1274.4	1274.8	1276	1275	1267.88
QG (Mvar)	321.08	272.27	276.58	309.1	304.4	271.34
Reduction in PLoss (%)	0	15.4	14.1	9.2	11.6	21.93
Total PLoss (Mw)	27.8	23.51	23.86	25.24	24.56	21.703

NR* - Not reported.

Then IEEE 300 bus system [18] is used as test system to validate the performance of the Projected Amplified Water Cycle Algorithm (AWCA).Table 10 shows the comparison of real power loss obtained after optimization.

Table 10 Comparison of Real Power Loss

Parameter	Method EGA [23]	Method EEA [23]	Method CSA [22]	AWCA
PLOSS (MW)	646.2998	650.6027	635.8942	617.0271

7. Conclusion

In this paper Amplified Water Cycle Algorithm (AWCA) has been successively solved the optimal reactive power problem. In the proposed Amplified Water Cycle Algorithm (AWCA) - with reference to the fitness value, population is first alienated into three groups: streams, rivers and sea. Through the hybridization of **Gravitational Search Algorithm,** Chaos theory with water cycle algorithm exploration and exploitation has been effectively improved. Projected Amplified Water Cycle Algorithm (AWCA) has been tested in standard IEEE 14, 30, 57, 300 bus test system and simulation results show the projected algorithm reduced the real power loss extensively. Percentage of the reduction of power loss is 23.46 %, 16.80%, 21.93% respectively.

References

[1] K. Y. Lee.(1984). "Fuel-cost minimisation for both real and reactive-power dispatches," *Proceedings Generation, Transmission and Distribution Conference*, vol/issue: 131(3), pp. 85-93.

[2] N. I. Deeb.(1998). "An efficient technique for reactive power dispatch using a revised linear programming approach," *Electric Power System Research*, vol/issue: 15(2), pp. 121–134.

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

[4] S. Granville.(1994). "Optimal reactive dispatch through interior point methods," *IEEE Transactions on Power System*, vol/issue: 9(1), pp. 136–146. http://dx.doi.org/10.1109/59.317548

[5] N. Grudinin.(1998). "Reactive power optimization using successive quadratic programming method," *IEEE Transactions on Power System*, vol/issue: 13(4), pp. 1219–1225. http://dx.doi.org/10.1109/59.736232

[6] Wei Yan, J. Yu, D. C. Yu , K. Bhattarai.(2006). "A new optimal reactive power flow model in rectangular form and its solution by predictor corrector primal dual interior point method", *IEEE Trans. Pwr. Syst*.,vol.21,no.1,pp.61-67. http://dx.doi.org/10.1109/TPWRS.2005.861978

[7] Aparajita Mukherjee, Vivekananda Mukherjee, (2015). "Solution of optimal reactive power dispatch by chaotic krill herd algorithm", *IET Gener. Transm. Distrib*, , Vol. 9, Issue. 15, pp. 2351–2362.

[8] Hu, Z., Wang, X. & Taylor.(2010). "Stochastic optimal reactive power dispatch: Formulation and solution method". *Electr. Power Energy Syst.*, vol. 32, pp. 615-621. http://dx.doi.org/10.1016/j.ijepes.2009.11.018

[9] Mahaletchumi A/P Morgan, Nor Rul Hasma Abdullah, Mohd Herwan Sulaiman,Mahfuzah Mustafa and Rosdiyana Samad.(2016). "Multi-Objective Evolutionary Programming (MOEP) Using Mutation Based on Adaptive Mutation Operator (AMO) Applied For Optimal Reactive Power Dispatch", *ARPN Journal of Engineering and Applied Sciences*, VOL. 11, NO. 14.

[10] Pandiarajan, K. & Babulal, C. K.(2016). " Fuzzy harmony search algorithm based optimal power flow for power system security enhancement". International Journal Electric Power Energy Syst., vol. 78, pp. 72-79.

[11] Mahaletchumi Morgan, Nor Rul Hasma Abdullah, Mohd Herwan Sulaiman, Mahfuzah Mustafa, Rosdiyana Samad.(2016). "Benchmark Studies on Optimal Reactive Power Dispatch (ORPD) Based Multi-objective Evolutionary Programming (MOEP) Using Mutation Based on Adaptive Mutation Adapter (AMO) and Polynomial Mutation Operator (PMO)", *Journal of Electrical Systems*, 12-1.

[12] Rebecca Ng Shin Mei, Mohd Herwan Sulaiman, Zuriani Mustaffa,. (2016). "Ant Lion Optimizer for Optimal Reactive Power Dispatch Solution" , Journal of Electrical Systems, "Special Issue AMPE2015", pp. 68-74.

[13] Gagliano A., Nocera F. (2017). Analysis of the performances of electric energy storage in residential applications, International Journal of Heat and Technology , Vol. 35, Special Issue 1, pp. S41-S48. DOI: 10.18280/ijht.35Sp0106.

[14] Caldera M., Ungaro P., Cammarata G., Puglisi G. (2018). Survey-based analysis of the electrical energy demand in Italian households, Mathematical Modelling of Engineering Problems, Vol. 5, No. 3, pp. 217-224. DOI: 10.18280/mmep.050313

[15] E. Rashedi, S. Nezamabadi, and S. Saryazdi, "GSA: A Gravitational Search Algorithm, "Information Sciences, vol. 179, no. 13, pp. 2232-2248, 2009.

[16] O. Abdel-Raouf, I. El-henawy and M. Abdel-Baset "chaotic Harmony Search Algorithm with Different Chaotic Maps for Solving Assignment Problems "International Journal of Computational Engineering & Management, Vol. 17, pp. 10-15 ,2014.

[17] Hadi Eskandar , Ali Sadollah , Ardeshir Bahreininejad , Mohd Hamdi, (2012) , "Water cycle algorithm - A novel metaheuristic optimization method for solving constrained engineering optimization problems", Computers and Structures, 110-111, p.151-166, November, doi>10.1016/j.compstruc.2012.07.010.

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

[19] Subbaraj, P. and P.N. Rajnarayan, 2009. Optimal reactive power dispatch using self-adaptive real coded Genetic algorithm. Electr. Power Syst. Res., 79(2): 374-38.

[20] Pandya, S. and R. Roy, 2015. Particle swarm optimization based optimal reactive power dispatch. Proceeding of the IEEE International Conference on Electrical, Computer and Communication Technologies (ICECCT), pp: 1-5.

[21] Ali Nasser Hussain, Ali Abdulabbas Abdullah and Omar Muhammed Neda, (2018),"Modified Particle Swarm Optimization for Solution of Reactive Power Dispatch", Research Journal of Applied Sciences, Engineering and Technology 15(8): 316-327, 2018 DOI:10.19026/rjaset.15.5917.

[22] S. Surender Reddy, "Optimal Reactive Power Scheduling Using Cuckoo Search Algorithm", International Journal of Electrical and Computer Engineering, Vol. 7, No. 5, pp. 2349-2356. 2017.

[23] 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.