INTERNATIONAL JOURNAL OF RESEARCH – GRANTHAALAYAH
A knowledge Repository

Science

COALESCED ALGORITHM FOR SOLVING REACTIVE POWER PROBLEM

Dr.K.Lenin [*1]
[*1] Researcher, Jawaharlal Nehru Technological University, Kukatpally, Hyderabad 500 085, India

DOI: https://doi.org/10.5281/zenodo.569974

Abstract

This paper combines Parallel Chaos Optimization Algorithm with Outlook Algorithm (PO) to solve optimal reactive power problem. The algorithm is organized in dual phases. The first phase uses parallel chaos optimization grounded on tent map for global exploration, while outlook algorithm is involved in the second phase for local exploration. The projected PO algorithm has been tested in standard IEEE 57,118 bus test systems and simulation results show clearly the improved performance of the proposed PO algorithm in declining the real power loss when compared to other reported standard algorithms.

Keywords: Chaos Optimization; Outlook Algorithm; Tent Map; Optimal Reactive Power; Transmission Loss.

Cite This Article: Dr.K.Lenin. (2017). "COALESCED ALGORITHM FOR SOLVING REACTIVE POWER PROBLEM." *International Journal of Research - Granthaalayah*, 5(4), 1-11. https://doi.org/10.5281/zenodo.569974.

1. Introduction

Reactive power optimization places an important role in optimal operation of power systems. Various numerical methods like the gradient method [1, 2], Newton method [3] and linear programming [4-7] have been implemented to solve the optimal reactive power dispatch problem. Both the gradient and Newton methods have the intricacy in managing inequality constraints. The problem of voltage stability and collapse play a key role in power system planning and operation [8] Evolutionary algorithms such as genetic algorithm have been already projected to solve the reactive power flow problem [9-11]. Evolutionary algorithm is a heuristic methodology used for minimization problems by utilizing nonlinear and non-differentiable continuous space functions. In [12], Hybrid differential evolution algorithm is projected to increase the voltage stability index. In [13] Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In [14], a fuzzy based method is used to solve the optimal reactive power scheduling method. In [15], an improved evolutionary programming is used to elucidate the optimal reactive power dispatch problem. In [16], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinear interior point method. In [17], a pattern algorithm is used to solve ac-dc optimal reactive power flow model with the generator capability limits. In [18-20] proposes a two-step approach to calculate Reactive power reserves with respect to operating constraints and voltage stability. This paper proposes Hybridization of chaos optimization algorithm with outlook algorithm (PO) to solve optimal reactive power problem. Chaos is a worldwide occurrence remaining in many systems in all areas of science [21]. It has three key vibrant properties: the inherent stochastic property, ergodicity and regularity [22]. A chaotic movement can go through every state in a certain area bestowing to its own regularity, and every state is attained only one. Taking benefit of chaos, a new penetrating algorithm called chaos optimization algorithm (COA) is presented [23]. The COA has the lack of the sensitive dependence on preliminary condition; minute difference in preliminary value, there may be carrying totally searching process. Some states may be reached costing longer time. Parallel chaos optimization algorithm was projected to solve this problem by searching synchronously from several preliminary points [24].While, further research show that this method has the inferior searching efficiency near the optimum point due to stochastic property of chaotic movement [25]. Outlook algorithm is proposed according to common knowledge that one chooses the highest point of mountains by outlook. It can solve global optimization problem by engaging supervision mechanism of outlook, policies of generating outlook points and mechanisms of building and solving local problems [26]. Outlook algorithm has great rate of convergence, fast exploration velocity and strong heftiness. The proposed Hybridized Parallel Chaos Optimization algorithm with Outlook Algorithm (PO) algorithm has been evaluated in standard IEEE 57,118 bus test systems. The simulation results show that proposed PO approach outperforms all the entitled reported algorithms in minimization of real power loss.

2. Problem Formulation

Main objective of the reactive power problem is to minimize the real power loss.

2.1.Active Power Loss

The objective of the reactive power dispatch problem is to minimize the active power loss and can be written in equations as follows:

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

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.

2.2.Voltage Profile Improvement

To minimize the voltage deviation in PQ buses, the objective function (F) can be written as:

$$F = P_L + \omega_v \times VD \qquad (2)$$

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

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \qquad (3)$$

Where Npq- number of load buses

2.3.Equality Constraint

The equality constraint of the problem is indicated by the power balance equation as follows:

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

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

2.4.Inequality Constraints

The inequality constraint implies the limits on components in the power system in addition to the limits created to make sure system security. Upper and lower bounds on the active power of slack bus (P_g), and reactive power of generators (Q_g) are written as follows:

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

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

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

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

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

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

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

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

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. Parallel Chaos Optimization Algorithm

Parallel Chaos Optimization Algorithm will probe the solution space by different numerous group chaos sequences. Firstly, use the carrier wave technique to make optimization variables vary to chaos variables. Secondly, intensify the ergodic area of chaotic motion to the variation ranges of every manageable variable. Finally, use the chaos search method to optimization problem.

The process is concise as follows,
Initialization

$$x_{(i.j,n+1)} = 4 * x_{(i,j,n)} * \left(1 - x_{(i,j,n)}\right) \quad (10)$$

Where i= 1,..,p, represents the different preliminary starting points of i classes, j = 1,.., N , articulates the variable number included in the optimized problem, n is the iteration times.

Carrying out the main carrier wave

The chaos variables are trade in into the optimized variables, furthermore, the change range of the chaos variables are distinctly augmented the corresponding value range of optimized variables.

$$x'_{(i,j,n+1)} = c_{(i,j)} + d_{(i,j)} * x_{(i,j,n+1)} \quad (11)$$

Where$x_{(i,j,n+1)}$ is chaos variable, $c_{(i,j)}$and$d_{(i,j)}$ are constants, $x'_{(i,j,n+1)}$is variable used for optimized problem.

Carrying out iteration exploration

In each generation, set the optimal solution of all classes as the existing solution. If no improved solution is found after N searches, the second carrier wave will be implemented according to the following equation:

$$x''_{(j,n+1)} = x_j^* + \alpha * x_{(j,n+1)} \quad (12)$$

Where x_j^* is the present solution, α is regulation constant, $x_{(j,n+1)}$ is chaos variable.

Execution of iteration search

If no improved solution is found after M searches, stopping search and output existing optimal solution.

Chaos Variables

Tent map has improved ergodicity consistency than logistic map, so the Parallel Chaos Optimization Algorithm based on tent map has improved optimization efficiency. In addition, tent map has simple structure and iteration process is appropriate for computing [27, 28]. In this paper chaos variables are produced by tent map. The tent map is defined by:

$$\gamma(k+1) = \begin{cases} 2\gamma(k) & 0 \le \gamma(k) \le 1/2 \\ 2\big(1-\gamma(k)\big) & 1/2 < \gamma(k) \le 1 \end{cases} \qquad (13)$$

After change transforming, it can be articulated as the following equation:

$$\gamma(k+1) = \big(2\gamma(k)\big) \bmod 1 \qquad (14)$$

4. Outlook Algorithm

Outlook algorithm self-possessed by three parts: direction mechanism of outlook, policies of generating outlook points and mechanisms of constructing and solving local problems. It can resolve global optimization problem bestowing to the following itinerary:

1) Compatible basic point by direction mechanism of outlook;
2) Producing outlook point of base point by policies of generating outlook points;
3) Selecting outlook point bestowing to given standard by direction mechanism of outlook;
4) Building the local problem of outlook point and resolving it by local optimization algorithm;
5) After receiving all the solutions of local problems chosen, conforming next base point and initiate a new iteration until satisfying end condition and set out solution.

5. Hybridization of parallel Chaos Optimization Algorithm with Outlook Algorithm

Initially, using Parallel Chaos Optimization Algorithm established on tent map for global exploration. It is easy to touch the region near global optimization solution owing to the ergodicity. Yet, Local searching speed become very slowly and it is difficult to get the high accuracy optimization solution due to the stochastic stuff of algorithm. Thus the outlook optimization algorithm is engaged in the second stage for local search. Extraordinary searching efficiency is obtained after bonding Parallel Chaos Optimization Algorithm with outlook algorithm. The technique is presented as follows:

Step i) Initialize chaos variable $\gamma_j^i(0), 0 \le \gamma_j^i(0) \le 1, (i = 1,2,..,n\ j = 1,2,..,P)$,by means of stochastic way, which have minor differences. There will produce p×n chaos variables having different track. The positive integers N1, N2 are quantified. Let flag = 1, C = 0, k = 0; where flag is outlook symbol, C is base point counter, k is iteration times.

Step ii) Chaos variable $\gamma_j^i(0)$ is mapped into the variance ranges of optimization variables by the following equation:

$$x_j^i(0) = a_i + \gamma_j^i(0)(b_i - a_i)$$
$$(i = 1,2,..,n\ j = 1,2..,P) \qquad (15)$$

Let $f_j^* = f\Big(X_j(0)\Big), X_j^* = X_j(0), f^* = \min\big(f_j^*\big), X^* = X_j^*$ .Where X_j^* is the best solution of the j team, X^* is the global best solution.

Step iii) Carry out chaos exploration by using the carrier wave:

$$\gamma_j^i(k+1) = \left(2\gamma_j^i(k)\right) \bmod 1 \qquad (16)$$

$$x_j^i(k+1) = a_i + (b_i - a_i)\gamma_j^i(k+1)$$
$$(i = 1,2,..,n \; j = 1,2,..,P) \qquad (17)$$

If $f\left(X_j(k+1)\right) < f_j^*$,
Then $X_j^* = X_j(k+1), f_j^* = f\left(X_j(k+1)\right)$
Else if $f\left(X_j(k+1)\right) \geq f_j^*$,
Then give up $X_j(k+1)$
If min $f_j^* < f^*$
Then $f^* = f_j^*$, $X^* = X_j^*$
Else do nothing
Let $k \leftarrow k+1$ until f^* does not progress after N1 searches.

Step iv) Set $X^B = X^*$, where X^B is outlook base point.

Step v) If flag = 1 and C < N2, Then carry out Step (vi) or Else go to step (vii).

Step vi) Generating outlook point of base point X_o^i $(i = 1,2,..,m)$ according to strategies of generating outlook points.

Step vii) While $f(X_i^o) \leq f(X^B)$ Carry out local search and get local optimum solution $X_i^l$from the point X_i^o . If min $f(X_i^l) < f(X^B)$ then $X^B = X_i^l$, flag = 1, return to step (vii). Or Else carry out step (viii).

Step viii) Halt the exploration process and put out X* = XB as the best solution, f * = f (XB) as the finest value.

6. Simulation Results

Proposed Hybridized Parallel Chaos Optimization Algorithm with Outlook Algorithm (PO) algorithm has been tested in standard IEEE-57 bus power system. The reactive power compensation buses are 18, 25 and 53. Bus 2, 3, 6, 8, 9 and 12 are PV buses and bus 1 is selected as slack-bus. The system variable limits are given in Table 1.

The preliminary conditions for the IEEE-57 bus power system are given as follows:

P_{load} = 12.016 p.u. Q_{load} = 3.013 p.u.

The total initial generations and power losses are obtained as follows:

$\sum P_G$ = 12.5521 p.u. $\sum Q_G$ = 3.3208 p.u.
P_{loss} = 0.25708 p.u. Q_{loss} = -1.2027 p.u.

Table 2 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after PO based optimization which are within the acceptable limits. In Table 3, shows the comparison of optimum results obtained from proposed PO with other optimization techniques. These results indicate the robustness of proposed PO approach for providing better optimal solution in case of IEEE-57 bus system.

Table 1: Variable limits

Reactive Power Generation Limits							
Bus no	1	2	3	6	8	9	12
Qgmin	-1.4	-.015	-.02	-0.04	-1.3	-0.03	-0.4
Qgmax	1	0.3	0.4	0.21	1	0.04	1.50

Voltage And Tap Setting Limits					
vgmin	**Vgmax**	**vpqmin**	**Vpqmax**	**tkmin**	**tkmax**
0.9	1.0	0.91	1.05	0.9	1.0

Shunt Capacitor Limits			
Bus no	18	25	53
Qcmin	0	0	0
Qcmax	10	5.2	6.1

Table 2: Control variables obtained after optimization

Control Variables	**PO**
V1	1.1
V2	1.041
V3	1.040
V6	1.031
V8	1.030
V9	1.012
V12	1.020
Qc18	0.0670
Qc25	0.200
Qc53	0.0470
T4-18	1.010
T21-20	1.060
T24-25	0.880
T24-26	0.881
T7-29	1.062
T34-32	0.881
T11-41	1.022
T15-45	1.040
T14-46	0.910
T10-51	1.021

T13-49	1.060
T11-43	0.910
T40-56	0.900
T39-57	0.950
T9-55	0.950

Table 3: Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [29]	0.25902	0.30854	0.27858
2	CGA [29]	0.25244	0.27507	0.26293
3	AGA [29]	0.24564	0.26671	0.25127
4	PSO-w [29]	0.24270	0.26152	0.24725
5	PSO-cf [29]	0.24280	0.26032	0.24698
6	CLPSO [29]	0.24515	0.24780	0.24673
7	SPSO-07 [29]	0.24430	0.25457	0.24752
8	L-DE [29]	0.27812	0.41909	0.33177
9	L-SACP-DE [29]	0.27915	0.36978	0.31032
10	L-SaDE [29]	0.24267	0.24391	0.24311
11	SOA [29]	0.24265	0.24280	0.24270
12	LM [30]	0.2484	0.2922	0.2641
13	MBEP1 [30]	0.2474	0.2848	0.2643
14	MBEP2 [30]	0.2482	0.283	0.2592
15	BES100 [30]	0.2438	0.263	0.2541
16	BES200 [30]	0.3417	0.2486	0.2443
17	Proposed PO	0.22120	0.23136	0.22162

Then proposed Hybridized Parallel Chaos Optimization Algorithm with Outlook Algorithm (PO) algorithm has been tested in standard IEEE 118-bus test system [31] .The system has 54 generator buses, 64 load buses, 186 branches and 9 of them are with the tap setting transformers. The limits of voltage on generator buses are 0.95 -1.1 per-unit., and on load buses are 0.95 -1.05 per-unit. The limit of transformer rate is 0.9 -1.1, with the changes step of 0.025. The limitations of reactive power source are listed in Table 4, with the change in step of 0.01.

Table 4: Limitation of reactive power sources

BUS	5	34	37	44	45	46	48
QCMAX	0	14	0	10	10	10	15
QCMIN	-40	0	-25	0	0	0	0
BUS	74	79	82	83	105	107	110
QCMAX	12	20	20	10	20	6	6
QCMIN	0	0	0	0	0	0	0

The statistical comparison results of 50 trial runs have been list in Table 5 and the results clearly show the better performance of proposed PO algorithm.

Table 5: Comparison results

Active power loss (MW)	BBO [32]	ILSBBO/ strategy1 [32]	ILSBBO/ strategy1 [33]	Proposed PO
Min	128.77	126.98	124.78	117.84
Max	132.64	137.34	132.39	120.65
Average	130.21	130.37	129.22	118.52

7. Conclusion

In this paper proposed Hybridized Parallel Chaos Optimization Algorithm with Outlook Algorithm (PO) algorithm has been successfully solved Optimal Reactive Power problem. The proposed Parallel Chaos Optimization Algorithm with Outlook Algorithm (PO) algorithm has been tested on the standard IEEE 57,118 test bus systems. Simulation results indicate the toughness of projected PO approach for providing better optimal solution in reducing the real power loss when compared to other standard reported algorithms.

References

[1] O.Alsac,and B. Scott, "Optimal load flow with steady state security",IEEE Transaction. PAS -1973, pp. 745-751.
[2] Lee K Y ,Park Y M , Oritz J L –A united approach to optimal real and reactive power dispatch , IEEE Transactions on power Apparatus and systems 1985: PAS-104 : 1147-1153
[3] A.Monticelli , M .V.F Pereira ,and S. Granville , "Security constrained optimal power flow with post contingency corrective rescheduling" , IEEE Transactions on Power Systems :PWRS-2, No. 1, pp.175-182.,1987.
[4] Deeb N ,Shahidehpur S.M ,Linear reactive power optimization in a large power network using the decomposition approach. IEEE Transactions on power system 1990: 5(2) : 428-435
[5] E. Hobson ,'Network consrained reactive power control using linear programming, ' IEEE Transactions on power systems PAS -99 (4) ,pp 868=877, 1980
[6] K.Y Lee ,Y.M Park , and J.L Oritz, "Fuel –cost optimization for both real and reactive power dispatches" , IEE Proc; 131C,(3), pp.85-93.
[7] M.K. Mangoli, and K.Y. Lee, "Optimal real and reactive power control using linear programming" , Electr.Power Syst.Res, Vol.26, pp.1-10,1993.
[8] C.A. Canizares , A.C.Z.de Souza and V.H. Quintana , " Comparison of performance indices for detection of proximity to voltage collapse ,'' vol. 11. no.3 , pp.1441-1450, Aug 1996 .
[9] S.R.Paranjothi ,and K.Anburaja, "Optimal power flow using refined genetic algorithm", Electr.Power Compon.Syst , Vol. 30, 1055-1063,2002.
[10] D. Devaraj, and B. Yeganarayana, "Genetic algorithm based optimal power flow for security enhancement", IEE proc-Generation.Transmission and. Distribution; 152, 6 November 2005.
[11] A.Berizzi, C. Bovo, M. Merlo, and M. Delfanti, "A ga approach to compare orpf objective functions including secondary voltage regulation," Electric Power Systems Research, vol. 84, no. 1, pp. 187 – 194, 2012.
[12] C.-F. Yang, G. G. Lai, C.-H. Lee, C.-T. Su, and G. W. Chang, "Optimal setting of reactive compensation devices with an improved voltage stability index for voltage stability enhancement," International Journal of Electrical Power and Energy Systems, vol. 37, no. 1, pp. 50 – 57, 2012.

[13] P. Roy, S. Ghoshal, and S. Thakur, “Optimal var control for improvements in voltage profiles and for real power loss minimization using biogeography based optimization,” International Journal of Electrical Power and Energy Systems, vol. 43, no. 1, pp. 830 – 838, 2012.
[14] B. Venkatesh, G. Sadasivam, and M. Khan, “A new optimal reactive power scheduling method for loss minimization and voltage stability margin maximization using successive multi-objective fuzzy lp technique,” IEEE Transactions on Power Systems, vol. 15, no. 2, pp. 844 – 851, may 2000.
[15] W. Yan, S. Lu, and D. Yu, “A novel optimal reactive power dispatch method based on an improved hybrid evolutionary programming technique,” IEEE Transactions on Power Systems, vol. 19, no. 2, pp. 913 – 918, may 2004.
[16] W. Yan, F. Liu, C. Chung, and K. Wong, “A hybrid genetic algorithm interior point method for optimal reactive power flow,” IEEE Transactions on Power Systems, vol. 21, no. 3, pp. 1163 – 1169, aug. 2006.
[17] J. Yu, W. Yan, W. Li, C. Chung, and K. Wong, “An unfixed piecewise optimal reactive power-flow model and its algorithm for ac-dc systems,” IEEE Transactions on Power Systems, vol. 23, no. 1, pp. 170 –176, feb. 2008.
[18] F. Capitanescu, “Assessing reactive power reserves with respect to operating constraints and voltage stability,” IEEE Transactions on Power Systems, vol. 26, no. 4, pp. 2224–2234, nov. 2011.
[19] Z. Hu, X. Wang, and G. Taylor, “Stochastic optimal reactive power dispatch: Formulation and solution method,” International Journal of Electrical Power and Energy Systems, vol. 32, no. 6, pp. 615 – 621, 2010.
[20] A.Kargarian, M. Raoofat, and M. Mohammadi, “Probabilistic reactive power procurement in hybrid electricity markets with uncertain loads,” Electric Power Systems Research, vol. 82, no. 1, pp. 68 – 80, 2012.
[21] Jefferies D J, Deane J H B, Johnstone G G. An introduction to chaos [J]. Electronics & Communication Engineering Journal, 1989, 1(3): 115-123.
[22] Wu X X, Chen Z. Introduction of chaos theory [J]. Shanghai Science and Technology Bibliographic Publishing House, Shanghai, 1996.
[23] JIANG B L I W. Optimizing complex functions by chaos search [J]. Cybernetics & Systems, 1998, 29(4): 409-419.
[24] Liang H Y, Gu X S. A novel chaos optimization algorithm based on parallel computing [J]. Journal of East China University of Science and Technology (Natural Science Edition), 2004, 30(4): 450-453.
[25] Wei T. Chaotic Optimization Method Based on Power Function Carrier and Its Applications [J]. Control and Decision, 2005, 9: 016.
[26] Yanguang Cai, Jixin Qian, and Youxian Sun. The global optimized outlook algorithm [J]. Journal of Guangdong University of Technology, 2006, 23(2):1-10.
[27] Shan L, Qiang H, Li J, et al. Chaotic optimization algorithm based on Tent map [J]. Control and Decision, 2005,20(2): 179-182.
[28] Xiaolan Wu and Guifang Guo, A hybrid global optimization algorithm based on parallel chaos optimization and outlook algorithm, Journal of Chemical and Pharmaceutical Research, 2014, 6(7):1884-1889.
[29] Chaohua Dai, Weirong Chen, Yunfang Zhu, and Xuexia Zhang, “Seeker optimization algorithm for optimal reactive power dispatch,” IEEE Trans. Power Systems, Vol. 24, No. 3, August 2009, pp. 1218-1231.
[30] J. R. Gomes and 0. R. Saavedra, “Optimal reactive power dispatch using evolutionary computation: Extended algorithms,” IEE Proc.-Gener. Transm. Distrib.. Vol. 146, No. 6. Nov. 1999.

[31] IEEE, “The IEEE 30-bus test system and the IEEE 118-test system”, (1993), http://www.ee.washington.edu/trsearch/pstca/.

[32] Jiangtao Cao, Fuli Wang and Ping Li, “An Improved Biogeography-based Optimization Algorithm for Optimal Reactive Power Flow” International Journal of Control and Automation Vol.7, No.3 (2014), pp.161-176.

*Corresponding author.
E-mail address: gklenin@gmail.com