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Reduction of Real Power Loss by using Comprehensive Neighbourhood Algorithm

K. Lenin [a*], Bhumanapally Ravindhranath Reddy [b]

[a]*Research Scholar,*

[b]*Deputy Executive Engineer,*

[a,b] *Jawaharlal Nehru Technological University Kukatpally,*

Hyderabad 500 085, India.

[a]gklenin@gmail.com

[b]*bumanapalli-brreddy@yahoo.co.in*

Abstract

In this paper, a new Comprehensive Neighbourhood Algorithm (CNA) is proposed to solve optimal reactive power dispatch problem. This algorithm is predominantly based on equilibrium between both the global and local search. A set of arbitrary solutions are primarily generated from the global search space, and then the best solution will give the optimal value. After that, the algorithm will iterate, and each iteration there will be two sets of generated solutions, one from the global search space and the other set of solutions will be produced from the neighbourhood of the best solution. The proposed Comprehensive Neighbourhood Algorithm (CNA) has been tested on standard IEEE 30, IEEE 57 bus test systems and simulation results show clearly thebetter performance of the proposed algorithm in reducing the real power loss.

Key words: Comprehensive Neighbourhood Algorithm, Optimal Reactive Power, Transmission loss,

1. Introduction

Optimal reactive power dispatch (ORPD) problem is to minimize the real power loss and bus voltage deviation. Variousnumericalmethodslike the gradient method [1-2], Newton method [3] and linear programming [4-7] have been adopted to solve the optimal reactive power dispatch problem.

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

Both the gradient and Newton methods have the complexity in managing inequality constraints. If linear programming is applied then the input- output function has to be uttered as a set of linear functions which mostly lead to loss of accuracy. The problem of voltage stability and collapse play a major role in power system planning and operation [8]. Evolutionary algorithms such as genetic algorithm have been already proposed to solve the reactive power flow problem [9-11]. Evolutionary algorithm is a heuristic approach used for minimization problems by utilizing nonlinear and non-differentiable continuous space functions.In [12], Hybrid differential evolution algorithm is proposed to improve the voltage stability index. In [13] Biogeography Based algorithm is projected to solve the reactive power dispatch problem. In [14], afuzzy based method is used to solve the optimal reactive power scheduling method. In [15], an improved evolutionary programming is used to solvethe optimal reactive power dispatch problem. In [16], the optimal reactive power flow problem is solved by integrating a genetic algorithm with a nonlinearinterior point method. In [17], apattern algorithm is used to solve ac-dc optimal reactive powerflow model with the generator capability limits. In [18], F. Capitanescu proposes a two-step approach to evaluate Reactive power reserves with respect to operating constraints and voltage stability. In [19], a programming based approachis used to solve the optimal reactive power dispatch problem. In [20], A. Kargarian et al present aprobabilistic algorithm for optimal reactive power provisionin hybrid electricity markets with uncertain loads. This paper proposes Comprehensive Neighbourhood Algorithm (CNA) to solvereactive power dispatch problem. A set of arbitrarily generated solutions from the entire explore space are first produced and then the best of these solutions is selected. After that, the algorithm will iterate, and in every iteration there will be two sets of produced solutions, one from the global explore space and the other set of solutions will be produced from the neighbourhood of the most excellent solution [21,22]. The proposed algorithm CNA hasbeen evaluated in standard IEEE 30 and IEEE57, bus test systems. The simulationresults show that our proposed approach outperforms allthe entitled reported algorithms in minimization of real power loss.

2. Problem Formulation

The optimal power flow problem is treated as a general minimization problem with constraints, and can be mathematically written in the following form:

Minimize f(x, u) (1)

subject to g(x,u)=0 (2)

and

$h(x, u) \leq 0$ (3)

where f(x,u) is the objective function. g(x.u) and h(x,u) are respectively the set of equality and inequality constraints. x is the vector of state variables, and u is the vector of control variables.

The state variables are the load buses (PQ buses) voltages, angles, the generator reactive powers and the slack active generator power:

$$x = \left(P_{g1}, \theta_2, \ldots, \theta_N, V_{L1}, \ldots, V_{LNL}, Q_{g1}, \ldots, Q_{gng}\right)^T \quad (4)$$

The control variables are the generator bus voltages, the shunt capacitors/reactors and the transformers tap-settings:

$$u = \left(V_g, T, Q_c\right)^T \quad (5)$$

or

$$u = \left(V_{g1}, \ldots, V_{gng}, T_1, \ldots, T_{Nt}, Q_{c1}, \ldots, Q_{cNc}\right)^T \quad (6)$$

Where ng, nt and nc are the number of generators, number of tap transformers and the number of shunt compensators respectively.

3. Objective Function

3.1. Active power loss

The objective of the reactive power dispatch is to minimize the active power loss in the transmission network, which can be described as follows:

$$F = PL = \sum_{k \in Nbr} g_k \left(V_i^2 + V_j^2 - 2V_iV_j \cos\theta_{ij}\right) \quad (7)$$

or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (8)$$

Where g_k: is the conductance of branch between nodes i and j, Nbr: is the total number of transmission lines in power systems. P_d: is the total active power demand, P_{gi}: is the generator active power of unit i, and P_{gsalck}: is the generator active power of slack bus.

3.2. Voltage profile improvement

For minimizing the voltage deviation in PQ buses, the objective function becomes:

$$F = PL + \omega_v \times VD \quad (9)$$

Where ω_v: is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (10)$$

3.3. Equality Constraint

The equality constraint g(x,u) of the ORPD problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses:

$$P_G = P_D + P_L \qquad (11)$$

This equation is solved by running Newton Raphson load flow method, by calculating the active power of slack bus to determine active power loss.

3.4. Inequality Constraints

The inequality constraints h(x,u) reflect the limits on components in the power system as well as the limits created to ensure system security. Upper and lower bounds on the active power of slack bus, and reactive power of generators:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \qquad (12)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max} \ , i \in N_g \qquad (13)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max} \ , i \in N \qquad (14)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max} \ , i \in N_T \qquad (15)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_C^{max} \ , i \in N_C \qquad (16)$$

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

4. Comprehensive Neighbourhood Algorithm

The projected methodology will work to discover the optimal value among these local optima by switching between exploration and exploitation. Exploration permits for exploring the whole search space. Exploitation permits focusing the search in the neighbourhood of the best solution of produced solutions.

The objective function we assume to explain the methodology is,,

$\min g = f(x_1, x_2, .., x_n)$ (17)

Where,

$x_1, x_2, .., x_n$, are the different combinations of the solution sequence.

We need to discover the optimal combination or solution$(X_1, X_2, .., X_n)$ that will give the optimal (minimum) value for the objective function .In general, if each of the variables $(X_1, X_2, .., X_n)$ can be chosen in $(n_1, n_2, .., n_n)$ ways respectively, then if we want to itemise all the possible solutions this will yield$(n_1, n_2, .., n_n)$ solutions.

According to the CNA algorithm, set of (m) arbitrary solutions are first arbitrarily generated from the set of all possible solution, where , $(X_1, X_2, .., X_n)$ can be chosen in$(n_1, n_2, .., n_n)$ ways. The generated solutions will then appear as:$(X_1^q, X_2^q, .., X_n^q)$ where $q = 1,2, .., m$.

The fitness for the above solution will be calculated and it can be done by substituting them in the objective function. The solutions are then classified according to their fitness obtained from the objective function.

$f(s_1) < f(s_2) < f(s_3) < \cdots < f(s_m)$ (18)

$s_1 = (X_1', X_2', .., X_n')$is the solution sequence with best fitness. The most excellent amalgamation(s_1) is then used as a high-quality measure for the local optimal solution and it is also primarily set as the finest known solution. In the next iteration, 50% of the (m) produced solutions will be generated near the most excellent solution neighbourhood by using a appropriate move operator. The other 50% of the (m) generated solutions will be still produced from the whole explore space, and the cause for that is to permit for the exploration of the search space, because if we just prefer the solutions close to the most excellent solution and we can find the local solution in the region of this point, and since the function that need to be optimized might have more than one local optima, which might guide us to get jammed at one of these local optima. Next, the best solution from the above (m) solutions (50%, 50%) is computed. The fresh value for the best solution is compared to best known solution and if it was found to be superior it will replace it. The process is then repeated until a certain end criterion is met. This end criterion can be a pre-specified number of iterations (t), or when there is no further enhancement on the final value of the optimal solution we obtained.

Step by step procedure of CNA

1. Start

2. Define objective function, variables and CNA parameters

3. Produce (m) feasible solutions from the entire explore space.

4. Using the objective function compute the fitness function for all produced (m) solutions.

5. Optimalsolution (OS) = fittest solution (most excellent solution)

6. I=0

7. Produce (50%$\times$ m) solutions from the neighbourhood of the fittest solution (most excellent) using a suitable move operator.

8. Produce (50%$\times$ m) solutions from the entire search space.

9. Find the fittest solution (most excellent) from above produced (m) solutions.

10. Is most excellent solutions (better than) optimal solution (OS)?

11. If yes, then OS = most excellent solution

12. If no, I=I+1

13. Is I< t?

14. If yes, then go to step 7

15. Or else stop.

CNA Code for optimal reactive power dispatch problem.

Describe objective function

Initialize the values for all parameters: m,t

Produce (m) feasible solutions from the search space

Calculate the fitness from the objective function

Optimal solution= the most excellent solution.

i=1

Do while i<t,++

Produce 50% × m solutions from the neighbourhood of the most excellent solution

Produce 50% × m solutions from the explorespace

Discover the most excellent solution from the (m) created solution

If most excellent solution is less (better) than optimal solution

Optimal solution=most excellent solution

End If

End DO

5. Simulation results

At first CNAalgorithm has been tested on the IEEE 30-bus, 41 branch system. It has a total of 13 control variables as follows: 6 generator-bus voltage magnitudes, 4 transformer-tap settings, and 2 bus shunt reactive compensators. Bus 1 is the slack bus, 2, 5, 8, 11 and 13 are taken as PV generator buses and the rest are PQ load buses. The considered security constraints are the voltage magnitudes of all buses, the reactive power limits of the shunt VAR compensators and the transformers tap settings limits. The variables limits are listed in Table 1.

Table 1: Initial Variables Limits (PU)

Control variables	Min. value	Max. value	Type
Generator: Vg	0.92	1.11	Continuous
Load Bus: VL	0.94	1.02	Continuous
T	0.94	1.02	Discrete
Qc	-0.11	0.31	Discrete

The transformer taps and the reactive power source installation are discrete with the changes step of 0.01. The power limits generators buses are represented in Table 2. Generators buses are: PV buses 2,5,8,11,13 and slack bus is 1.the others are PQ-buses.

Table 2: Generators Power Limits in MW and MVAR

Bus n°	Pg	Pgmin	Pgmax	Qgmin
1	98.00	51	202	-21
2	81.00	22	81	-21
5	53.00	16	53	-16
8	21.00	11	34	-16
11	21.00	11	29	-11
13	21.00	13	41	-16

Table 3: Values of Control Variables after Optimization and Active Power Loss

Control Variables (p.u)	CNA
V1	1.0650
V2	1.0557
V5	1.0321
V8	1.0450
V11	1.0859
V13	1.0659
T4,12	0.00
T6,9	0.02
T6,10	0.90
T28,27	0.91
Q10	0.11
Q24	0.11
PLOSS	4.9193
VD	0.9070

The proposed approach succeeds in keeping the dependent variable within their limits is shown in Table 3.

Table 4 summarizes the results of the optimal solution obtained by PSO, SGA and CNA methods. It reveals the reduction of real power loss after optimization.

Table 4: Comparison Results of Different Methods

SGA[23]	PSO[24]	CNA
4.98 Mw	4.9262Mw	4.9193Mw

Secondly the proposed hybrid CNAalgorithm for solving ORPD problem is tested for standard IEEE-57 bus power system. The IEEE 57-bus system data consists of 80 branches, seven generator-buses and 17 branches under load tap setting transformer branches. The possible 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. In this case, the search space has 27 dimensions, i.e., the seven generator voltages, 17 transformer taps, and three capacitor banks. The system variable limits are given in Table 5. The initial conditions for the IEEE-57 bus power system are given as follows:

P_{load}= 12.421p.u. Q_{load} = 3.332p.u.

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

$\sum P_G$ = 12.7721p.u. $\sum Q_G$ = 3.4552p.u.

P_{loss}= 0.27449p.u. Q_{loss} = -1.2241p.u.

Table 6 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after CNA based optimization which are within their acceptable limits. In Table 7, a comparison of optimum results obtained from proposed CNA with other optimizationtechniques for ORPD mentioned in literature for IEEE-57bus power system is given. These results indicate the robustness of proposed CNAapproach for providing better optimalsolution in case of IEEE-57 bus system.

Table 5: Variables limits for ieee-57 bus power system (p.u.)

REACTIVE POWER GENERATION LIMITS							
BUS NO	1	2	3	6	8	9	12
Q_{GMIN}	-1.1	-.011	-.01	-0.02	-1.2	-0.01	-0.1
Q_{GMAX}	1	0.1	0.1	0.23	1	0.01	1.50
VOLTAGE AND TAP SETTING LIMITS							
V_{GMIN}	V_{GMAX}	V_{PQMIN}	V_{PQMAX}	T_{KMIN}	T_{KMAX}		
0.5	1.0	0.91	1.01	0.5	1.0		
SHUNT CAPACITOR LIMITS							
BUS NO	18	25	53				
Q_{CMIN}	0	0	0				
Q_{CMAX}	10	5.1	6.2				

Table 6: control variables obtained after optimization by CNA method for ieee-57 bus system (p.u.).

Control Variables	CNA
V1	1.1
V2	1.065
V3	1.054

V6	1.043
V8	1.060
V9	1.031
V12	1.041
Qc18	0.0849
Qc25	0.339
Qc53	0.0629
T4-18	1.018
T21-20	1.059
T24-25	0.960
T24-26	0.930
T7-29	1.075
T34-32	0.939
T11-41	1.011
T15-45	1.059
T14-46	0.929
T10-51	1.039
T13-49	1.059
T11-43	0.911
T40-56	0.903
T39-57	0.960
T9-55	0.970

Table 7: comparative optimization results for ieee-57 bus power system (p.u.)

S.No.	Optimization Algorithm	Best Solution	Worst Solution	Average Solution
1	NLP [25]	0.25902	0.30854	0.27858
2	CGA [25]	0.25244	0.27507	0.26293
3	AGA [25]	0.24564	0.26671	0.25127
4	PSO-w [25]	0.24270	0.26152	0.24725
5	PSO-cf [25]	0.24280	0.26032	0.24698
6	CLPSO [25]	0.24515	0.24780	0.24673
7	SPSO-07 [25]	0.24430	0.25457	0.24752
8	L-DE [25]	0.27812	0.41909	0.33177
9	L-SACP-DE [25]	0.27915	0.36978	0.31032
10	L-SaDE [25]	0.24267	0.24391	0.24311

11	SOA [25]	0.24265	0.24280	0.24270
12	LM [26]	0.2484	0.2922	0.2641
13	MBEP1 [26]	0.2474	0.2848	0.2643
14	MBEP2 [26]	0.2482	0.283	0.2592
15	BES100 [26]	0.2438	0.263	0.2541
16	BES200 [26]	0.3417	0.2486	0.2443
17	Proposed CNA	0.22341	0.23468	0.23122

6. Conclusion

CNA algorithm has been effectivelyapplied for ORPD problem. CNA based ORPD is tested in standard IEEE 30, IEEE 57 bus system. Performance comparisons with well-known population-based algorithms give encouraging results. CNAemerges to find good solutions when compared to that of other algorithms. The simulation results presented in previous section prove the ability of CNA approach to arrive at near global optimal solution.

References

[1] O.Alsac, B. Scott, "Optimal load flow with steady state security",IEEE Transaction. PAS -1973, pp. 745-751.

[2] Lee K Y ,Paru 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 tocompare 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, “Optimalsetting of reactive compensation devices with an improved voltagestability index for voltage stability enhancement,” International Journalof 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 improvementsin voltage profiles and for real power loss minimization usingbiogeography based optimization,” International Journal of ElectricalPower and Energy Systems, vol. 43, no. 1, pp. 830 – 838, 2012.

[14] B. Venkatesh, G. Sadasivam, and M. Khan, “A new optimal reactivepower scheduling method for loss minimization and voltage stabilitymargin 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 dispatchmethod 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 algorithminteriorpoint method for optimal reactive power flow,” IEEE Transactionson 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 piecewiseoptimalreactive 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 tooperating constraints and voltage stability,” IEEE Transactions on PowerSystems, vol. 26, no. 4, pp. 2224–2234, nov. 2011.

[19] Z. Hu, X. Wang, and G. Taylor, “Stochastic optimal reactive powerdispatch: Formulation and solution method,” International Journal ofElectrical Power and Energy Systems, vol. 32, no. 6, pp. 615 – 621,2010.

[20] A. Kargarian, M. Raoofat, and M. Mohammadi, “Probabilistic reactivepower procurement in hybrid electricity markets with uncertain loads,”Electric Power Systems Research, vol. 82, no. 1, pp. 68 – 80, 2012.

[21] T. Weise, Global Optimization Algorithms – Theory and Application, Germany: it-weise.de (self-published), [Online]. Available: http://www.it-weise.de/, 2009.

[22]. Azmi Alazzam and Harold W. Lewis III- A New Optimization Algorithm For Combinatorial Problems, International Journal of Advanced Research in Artificial Intelligence, Vol. 2, No.5, 2013.

[23] Q.H. Wu, Y.J.Cao, and J.Y. Wen. Optimal reactive power dispatch using an adaptive genetic algorithm. Int. J. Elect. Power Energy Syst. Vol 20. Pp. 563-569; Aug 1998.

[24] B. Zhao, C. X. Guo, and Y.J. CAO. Multiagent-based particle swarm optimization approach for optimal reactive power dispatch. IEEE Trans. Power Syst. Vol. 20, no. 2, pp. 1070-1078, May 2005.

[25]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.

[26] 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.

K. Lenin has received his B.E., Degree, electrical and electronics engineering in 1999 from university of madras, Chennai, India and M.E., Degree in power systems in 2000 from Annamalai University, TamilNadu, India. At present pursuing Ph.D., degree at JNTU, Hyderabad,India.

Bhumanapally.RavindhranathReddy, Born on 3rd September,1969. Got his B.Tech in Electrical & Electronics Engineering from the J.N.T.U. College of Engg., Anantapur in the year 1991. Completed his M.Tech in Energy Systems in IPGSR of J.N.T.University Hyderabad in the year 1997. Obtained his doctoral degree from JNTUA,Anantapur University in the field of Electrical Power Systems. Published 12 Research Papers and presently guiding 6 Ph.D. Scholars. He was specialized in Power Systems, High Voltage Engineering and Control Systems. His research interests include Simulation studies on Transients of different power system equipment.