



Science

WIDE-RANGING VICINITY ALGORITHM FOR SOLVING OPTIMAL REACTIVE POWER PROBLEM

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Abstract

In this paper, Wide-ranging vicinity Algorithm (WVA) is proposed to solve optimal reactive power problem. Wide-ranging vicinity Algorithm equally improves the local & global search. From the global search space a set of arbitrary solutions are primarily generated and then the most excellent solution will give the optimal value. After that, the algorithm will iterate, & there will be two sets of generated solutions in iteration's, one from the global search space, the other from the set of solutions & it will be produced from the vicinity of the most excellent solution. The proposed Wide-ranging vicinity Algorithm (WVA) has been tested on standard IEEE 118 & practical 191 bus test systems and simulation results show clearly the superior performance of the proposed Wide-ranging vicinity Algorithm (WVA) in reducing the real power loss & voltage profiles are within the limits.

Keywords: Ranging Vicinity Algorithm; Local & Global Search; Optimal Reactive Power; Transmission Loss.

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1. Introduction

The main objective of optimal reactive power problem is to minimize the real power loss and bus voltage deviation. Various numerical methods like the gradient method [1-2], Newton method [3] and linear programming [4-7] have been adopted to solve the optimal reactive power dispatch problem. 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], a fuzzy based method is used to solve the optimal reactive power scheduling method. In [15], an improved evolutionary programming is used to solve 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], 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 approaches used to solve the optimal reactive power dispatch problem. In [20], A. Kargarian et al present a probabilistic algorithm for optimal reactive power provision in hybrid electricity markets with uncertain loads. In this paper, Wide-ranging vicinity Algorithm (WVA) is proposed to solve optimal reactive power problem. Wide-ranging vicinity Algorithm equally improves the local & global search. From the global search space a set of arbitrary solutions are primarily generated and then the most excellent solution will give the optimal value. After that, the algorithm will iterate, & there will be two sets of generated solutions in iteration's, one from the global search space, the other from the set of solutions & it will be produced from the vicinity of the most excellent solution. The proposed Wide-ranging vicinity Algorithm (WVA) has been tested on standard IEEE 118 & practical 191 bus test systems and simulation results show clearly the superior performance of the proposed Wide-ranging vicinity Algorithm (WVA) in reducing the real power loss & voltage profiles are within the limits.

2. Problem Formulation

2.1. Active Power Loss

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

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

Or

$$F = PL = \sum_{i \in Ng} P_{gi} - P_d = P_{gslack} + \sum_{i \neq slack}^{Ng} P_{gi} - P_d \quad (2)$$

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_{gslack} : is the generator active power of slack bus.

2.2. Voltage Profile Improvement

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

$$F = PL + \omega_v \times VD \quad (3)$$

Where ω_v : is a weighting factor of voltage deviation.

VD is the voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \quad (4)$$

2.3. Equality Constraint

The equality constraint of the problem is represented by the power balance equation, where the total power generation must cover the total power demand and the power losses,

$$P_G = P_D + P_L \quad (5)$$

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

2.4. Inequality Constraints

The inequality constraints 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:

$$P_{gslack}^{min} \leq P_{gslack} \leq P_{gslack}^{max} \quad (6)$$

$$Q_{gi}^{min} \leq Q_{gi} \leq Q_{gi}^{max}, i \in N_g \quad (7)$$

Upper and lower bounds on the bus voltage magnitudes:

$$V_i^{min} \leq V_i \leq V_i^{max}, i \in N \quad (8)$$

Upper and lower bounds on the transformers tap ratios:

$$T_i^{min} \leq T_i \leq T_i^{max}, i \in N_T \quad (9)$$

Upper and lower bounds on the compensators reactive powers:

$$Q_c^{min} \leq Q_c \leq Q_c^{max}, i \in N_C \quad (10)$$

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.

3. Wide-Ranging Vicinity Algorithm (WVA)

The proposed Wide-ranging vicinity Algorithm (WVA) will work to discover the optimal value among the 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,

$$\min g = f(x_1, x_2, \dots, x_n) \quad (11)$$

Where,

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

We need to discover the optimal combination or solution (X_1, X_2, \dots, X_n) that will give the optimal (minimum) value for the objective function. In general, if each of the variables (X_1, X_2, \dots, X_n) can be chosen in (n_1, n_2, \dots, n_n) ways respectively, then if we want to enumerate all the possible solutions this will yield (n_1, n_2, \dots, n_n) solutions [21,22].

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

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.

$$f(s_1) < f(s_2) < f(s_3) < \dots < f(s_m) \quad (12)$$

$s_1 = (X'_1, X'_2, \dots, X'_n)$ 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 neighborhood 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.

Wide-ranging vicinity Algorithm (WVA) for solving optimal reactive power problem

- a. Start
- b. Define objective function, variables and WVA parameters
- c. Produce (m) feasible solutions from the entire explore space.
- d. Using the objective function compute the fitness function for all produced (m) solutions.
- e. Optimal solution (OS) = fittest solution (most excellent solution)
- f. I=0
- g. Produce ($50\% \times m$) solutions from the neighbourhood of the fittest solution (most excellent) using a suitable move operator.
- h. Produce ($50\% \times m$) solutions from the entire search space.

- i. Find the fittest solution (most excellent) from above produced (m) solutions.
- j. Is most excellent solutions (better than) optimal solution (OS)?
- k. If yes, then OS = most excellent solution
- l. If no, $I=I+1$
- m. Is $I < t$?
- n. If yes, then go to step g
- o. Or else stop.

Portray objective function

Initialize the values for all parameters: m,t

Generate (m) feasible solutions from the exploration space

Compute the fitness from the objective function

Optimal solution= the most excellent solution.

$i=1$

Do while $I < t, ++$

Generate $50\% \times m$ solutions from the vicinity of the most excellent solution

Generate $50\% \times m$ solutions from the explore space

Find out the most excellent solution from the (m) formed solution

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

Optimal solution=most excellent solution

End If

End DO

4. Simulation Results

At first Wide-ranging vicinity Algorithm (WVA) has been tested in standard IEEE 118-bus test system [23].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 1, with the change in step of 0.01.

Table 1: Limitation of reactive power sources

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

The statistical comparison results of 50 trial runs have been list in Table 2 and the results clearly show the better performance of proposed Wide-ranging vicinity Algorithm (WVA) approach.

Table 2: Comparison results

Active power loss (p.u)	BBO [24]	ILSBBO/strategy1 [24]	ILSBBO/strategy1 [24]	Proposed WVA
Min	128.77	126.98	124.78	117.48
Max	132.64	137.34	132.39	122.96
Average	130.21	130.37	129.22	119.52

Then the Wide-ranging vicinity Algorithm (WVA) has been tested in practical 191 test system and the following results have been obtained. In Practical 191 test bus system – Number of Generators = 20, Number of lines = 200, Number of buses = 191 Number of transmission lines = 55. Table 3 shows the optimal control values of practical 191 test system obtained by WVA method. And table 4 shows the results about the value of the real power loss by obtained by Wide-ranging vicinity Algorithm (WVA).

Table 3: Optimal Control values of Practical 191 utility (Indian) system by WVA method

VG1	1.100		VG 11	0.900
VG 2	0.780		VG 12	1.000
VG 3	1.010		VG 13	1.000
VG 4	1.010		VG 14	0.900
VG 5	1.100		VG 15	1.000
VG 6	1.100		VG 16	1.000
VG 7	1.100		VG 17	0.900
VG 8	1.010		VG 18	1.000
VG 9	1.100		VG 19	1.100
VG 10	1.010		VG 20	1.100

T1	1.000		T21	0.900		T41	0.900
T2	1.000		T22	0.900		T42	0.900
T3	1.000		T23	0.900		T43	0.910
T4	1.100		T24	0.900		T44	0.910
T5	1.000		T25	0.900		T45	0.910
T6	1.000		T26	1.000		T46	0.900
T7	1.000		T27	0.900		T47	0.910
T8	1.010		T28	0.900		T48	1.000
T9	1.000		T29	1.010		T49	0.900
T10	1.000		T30	0.900		T50	0.900
T11	0.900		T31	0.900		T51	0.900
T12	1.000		T32	0.900		T52	0.900
T13	1.010		T33	1.010		T53	1.000
T14	1.010		T34	0.900		T54	0.900
T15	1.010		T35	0.900		T55	0.900
T19	1.020		T39	0.900			
T20	1.010		T40	0.900			

Table 4: Optimum real power loss values obtained for practical 191 utility (Indian) system by WVA method.

Real power Loss (MW)	WVA
Min	146.184
Max	149.128
Average	147.006

5. Conclusion

Wide-ranging vicinity Algorithm (WVA) algorithm has been successfully applied to solve optimal reactive power problem. Wide-ranging vicinity Algorithm equally improves the local & global search. From the global search space a set of arbitrary solutions are primarily generated and then the most excellent solution given the optimal value. The proposed Wide-ranging vicinity Algorithm (WVA) has been tested on standard IEEE 118 & practical 191 bus test systems and simulation results show clearly the superior performance of the proposed Wide-ranging vicinity Algorithm (WVA) in reducing the real power loss & voltage profiles are within the limits.

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