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ACTIVE POWER LOSS REDUCTION BY SYNTHESIZED ALGORITHM

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Abstract

In this paper, Synthesized Algorithm (SA) proposed to solve the optimal reactive power problem. Proposed Synthesized Algorithm (SA) is a combination of three well known evolutionary algorithms, namely Differential Evolution (DE) algorithm, Particle Swarm Optimization (PSO) algorithm, and Harmony Search (HS) algorithm. It merges the general operators of each algorithm recursively. This achieves both good exploration and exploitation in SA without altering their individual properties. In order to evaluate the performance of the proposed SA, it has been tested in Standard IEEE 57,118 bus systems and compared to other standard reported algorithms. Simulation results show's that Synthesized Algorithm (SA) successfully reduces the real power loss and voltage profiles are within the limits.

Keywords: Particle Swarm Optimization; Genetic Algorithm; Harmony Search; Optimal Reactive Power; Transmission Loss.

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1. Introduction

Optimal reactive power dispatch problem is one of the difficult optimization problems in power systems. The sources of the reactive power are the generators, synchronous condensers, capacitors, static compensators and tap changing transformers. The problem that has to be solved in a reactive power optimization is to determine the required reactive generation at various locations so as to optimize the objective function. Here the optimal reactive power problem involves best utilization of the existing generator bus voltage magnitudes, transformer tap setting and the output of reactive power sources so as to minimize the real power loss and to keep the voltage profiles within the limits. Various mathematical techniques have been adopted to solve this optimal reactive power dispatch problem. These include the gradient method [1-2], Newton method [3] and linear programming [4-7].The gradient and Newton methods suffer from the difficulty in handling inequality constraints. To apply linear programming, the input- output function is to be expressed as a set of linear functions which may lead to loss of accuracy. Recently global Optimization techniques such as genetic algorithms have been proposed to solve the reactive power flow

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problem [8, 9]. Each optimization algorithm uses different properties to keep a balance between the exploration and exploitation goals which can be a key for the success of an algorithm. Exploration attribute of an algorithm enables the algorithm to test several areas in the search space. On the other hand, exploitation attribute makes the algorithm focus the search around the possible candidates. Although the optimization algorithms have positive characteristics, it is shown that these algorithms do not always perform as well as it is desired. Because of this, hybrid algorithms are growing area of interest since their solution quality can be made better than the algorithms that form them by combining their desirable features. Hybridization is simply the combination of two or more techniques in order to outperform their performances by the use of their good properties together. In this paper, Synthesized Algorithm (SA) proposed to solve the optimal reactive power problem. Hybridization has been done in several different ways in the literature and it is observed that the new hybridization techniques are very efficient and effective for optimization [10-15]. A novel hybrid algorithm proposed in this paper is called HA and it is a combination of three well known evolutionary algorithms, namely Differential Evolution (DE) algorithm, Particle Swarm Optimization (PSO) algorithm, and Harmony Search (HS) algorithm. It merges the general operators of each algorithm recursively. This achieves both good exploration and exploitation in SA without altering their individual properties. In order to evaluate the performance of the proposed SA, it has been tested in Standard IEEE 57,118 bus systems and compared to other standard reported algorithms. Simulation results show's that Synthesized Algorithm (SA) successfully reduces the real power loss and voltage profiles are within the limits.

2. Problem Formulation

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:

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

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 Profile Improvement

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

$$F = PL + \omega_v \times VD \quad (2)$$

Where VD - voltage deviation,ω_v- is a weighting factor of voltage deviation.

Voltage deviation given by:

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

Where Npq- number of load buses

Equality Constraint

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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:

$$P_G = P_D + P_L \tag{4}$$

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

Inequality Constraints

The inequality constraints 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 (Pg), and reactive power of generators (Q_g) are written in mathematically as follows:

$$P_{gslack}^{min} \le P_{gslack} \le P_{gslack}^{max} \tag{5}$$

$$Q_{gi}^{min} \le Q_{gi} \le Q_{gi}^{max} , i \in N_g \tag{6}$$

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

$$V_i^{min} \le V_i \le V_i^{max} , i \in N \tag{7}$$

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

$$T_i^{min} \le T_i \le T_i^{max} , i \in N_T \tag{8}$$

Upper and lower bounds on the compensators reactive powers (Q_c):

$$Q_c^{min} \le Q_c \le Q_C^{max} , i \in N_C \tag{9}$$

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. Synthesized Algorithm (SA)

In the literature, many different ways of combining the well-known algorithms are performed to obtain more powerful optimization algorithms [10-15]. The main aim of the hybridization is to use different properties of different algorithms to improve the solution quality.

Among the well-known algorithms, DE, PSO and HS algorithms are the three algorithms that are used in many fields by researchers and these algorithms are proven to be very powerful optimization tools. Each algorithm has different strong features. As an example, DE usually requires less computational time and also has better approximation of solutions for most of the problems. PSO generally avoids the solution from trapping into local minima by using its diversity. HS on the other hand, is an efficient algorithm that has a very good performance on different applications.

HA uses the operators of these three algorithms with randomly selected parameters consecutively and by not altering their properties. The new candidate set, obtained by each algorithm, is used as a new solution set for the other algorithm.

SA algorithm for Solving Optimal Reactive Power Problem

Step 1. Generation of the candidate population with given dimensions: Initialize the candidate population X_{ij} in a given range.

Step 2. *Crossover and mutation operators of DE:* The mutation and crossover operators are applied to find the better approximation to a solution by using (10), (11), and (12).

The mutant vector V_{ij} is calculated as corresponding to each member in population using (10) where *a*, *b*, and *c* are distinct numbers. Mutant vector V_{ij} is crossover with X_{ij} and trial vector U_{ij} is generated by using (11) where rj is a uniformly distributed number for each j^{th} parameter of X_i. Also, *F* and *CR* are the main control parameters of DE.

$$V_i = X_a + F(X_b - X_c) \tag{10}$$

$$U_{ij} = \begin{cases} V_{ij} \; if \; r_j \leq CR \\ X_{ij} \; otherwise \end{cases} \tag{11}$$

$$X_i = \begin{cases} U_i \; if \; f(U_i) < f(X_i) \\ X_i \; otherwise \end{cases} \tag{12}$$

Selection process determines U_{ij} to survive to the next generation by using (12).

Step 3. *Particle movement by PSO:* The randomly selected parameters are applied on the velocities by using (13). When a better solution is being discovered, all particles improve their positions by using (14). This movement avoids the particles to be trapped to the local minima by increasing the diversity of solution. V_{ij} refers to the velocity values and for each row is calculated according to the control parameters c_1, c_2, and w by using (13). $global_{best}$ is the best position obtained by any particle and P_{best} is the personal best of a particle. X_{ij} refers to current positions of a particle and can be updated by using (14) for each row.

$$V_i = w * V_i + c_1 * (P_{best} - X_i) + c_2 * (global_{best} - X_i) \tag{13}$$

$$X_i = X_i + V_i \tag{14}$$

Step 4. *Choosing a neighbouring value by HS:* HS can search in different zones of the search space by using the control parameters that are *hmcr*, *par* and *fw*. With a given probability of *hmcr*, a value is selected from the candidate population. With a given probability of 1-*hmcr*, a random candidate is generated in the given range. The population can have non-updated candidates to keep the diversity in the population with a given probability of 1-*par*. With a given probability of *par*, the candidates are updated by applying (15) where rand() is a random number ∈ (-1,1).

$$X_i = X_i + rand\,() * f\,w \tag{15}$$

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Step 5. Consecutively Step 2, Step 3, and Step 4 are applied. The algorithm is performed until the termination criterion is not satisfied.

4. Simulation Results

At first Synthesized Algorithm (SA) 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} = 12.108 p.u. Q_{load} = 3.084 p.u.
The total initial generations and power losses are obtained as follows:
$\sum P_G$ = 12.472 p.u. $\sum Q_G$ = 3.3186 p.u.
P_{loss} = 0.25854 p.u. Q_{loss} = -1.2068 p.u.

Table 2 shows the various system control variables i.e. generator bus voltages, shunt capacitances and transformer tap settings obtained after optimization which are within the acceptable limits. In Table 3, shows the comparison of optimum results obtained from proposed methods with other optimization techniques. These results indicate the robustness of proposed approaches 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	**SA**
V1	1.10
V2	1.030
V3	1.031
V6	1.020
V8	1.022
V9	1.002
V12	1.014

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Qc18	0.0660
Qc25	0.201
Qc53	0.0472
T4-18	1.000
T21-20	1.042
T24-25	0.860
T24-26	0.871
T7-29	1.050
T34-32	0.872
T11-41	1.016
T15-45	1.032
T14-46	0.912
T10-51	1.020
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 [16]	0.25902	0.30854	0.27858
2	CGA [16]	0.25244	0.27507	0.26293
3	AGA [16]	0.24564	0.26671	0.25127
4	PSO-w [16]	0.24270	0.26152	0.24725
5	PSO-cf [16]	0.24280	0.26032	0.24698
6	CLPSO [16]	0.24515	0.24780	0.24673
7	SPSO-07 [16]	0.24430	0.25457	0.24752
8	L-DE [16]	0.27812	0.41909	0.33177
9	L-SACP-DE [16]	0.27915	0.36978	0.31032
10	L-SaDE [16]	0.24267	0.24391	0.24311
11	SOA [16]	0.24265	0.24280	0.24270
12	LM [17]	0.2484	0.2922	0.2641
13	MBEP1 [17]	0.2474	0.2848	0.2643
14	MBEP2 [17]	0.2482	0.283	0.2592
15	BES100 [17]	0.2438	0.263	0.2541
16	BES200 [17]	0.3417	0.2486	0.2443
17	Proposed SA	0.22004	0.23026	0.22208

Then Synthesized Algorithm (SA) has been tested in standard IEEE 118-bus test system [18].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 has been listed in Table 5 and the results clearly show the better performance of proposed Synthesized Algorithm (SA) in reducing the real power loss.

Table 5: Comparison results

Active power loss (MW)	**BBO [19]**	**ILSBBO/ strategy1 [19]**	**ILSBBO/ strategy1 [19]**	**Proposed SA**
Min	128.77	126.98	124.78	112.98
Max	132.64	137.34	132.39	116.02
Average	130.21	130.37	129.22	114.54

5. Conclusion

In this paper, Synthesized Algorithm (SA) has been successfully solved optimal reactive power problem. Proposed Synthesized Algorithm (SA) is a combination of three well known evolutionary algorithms, namely Differential Evolution (DE) algorithm, Particle Swarm Optimization (PSO) algorithm, and Harmony Search (HS) algorithm. It merges the general operators of each algorithm recursively. This achieves both good exploration and exploitation in SA without altering their individual properties. In order to evaluate the performance of the proposed SA, it has been tested in Standard IEEE 57,118 bus systems and compared to other standard reported algorithms. Simulation results show's that Synthesized Algorithm (SA) successfully reduces the real power loss and voltage profiles are within the limits.

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