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REDUCTION OF ACTIVE POWER LOSS BY IMPROVED TABU SEARCH ALGORITHM

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Abstract

In this paper, an Improved Tabu Search (ITS) algorithm has been proposed to solve the optimal reactive power problem. In this work Tabu Search- has been hybridized with Simulated Annealing algorithm to solve the optimal reactive power problem. Hybridization of these two algorithms improves the exploration & exploitation capabilities during the search. Proposed Improved Tabu Search (ITS) algorithm has been tested in Standard IEEE 57,118 bus systems & real power loss has been comparatively reduced with voltage profiles are within the limits.

Keywords: Tabu Search; Simulated Annealing; Reactive Power Problem; Transmission Loss.

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1. Introduction

Optimal reactive power problem is key problem in secure & economic operations of power system. 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 reactive power dispatch 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 loss and to enhance the voltage stability of the system. It involves a non linear optimization problem. 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 problem [8, 9]. This paper proposes an Improved Tabu Search (ITS) algorithm has been proposed to solve the optimal reactive power problem. In this work Tabu Search- has been hybridized with Simulated Annealing algorithm to solve the optimal reactive power problem.

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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:

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

Where F- objective function, P_L – power loss, g_k-conductance of branch, Vi 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:

$$F = PL + \omega_v \times VD \tag{2}$$

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

Voltage deviation given by:

$$VD = \sum_{i=1}^{Npq} |V_i - 1| \tag{3}$$

Where Npq- number of load buses

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:

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

Where P_G- total power generation, PD - 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:

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

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

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

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

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

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

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

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

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. Tabu Search

Tabu search (TS), which was firstly developed by Glover [10-12]. Neighbourhood explorations take a potential solution to a problem and authenticate its instantaneous local opportunities, which is, solutions that are similar except for one or two minor details to recognize a better-quality solution. Local search methods incline to become stuck in suboptimal regions. Tabu search takes benefit of the performance of these approaches by using memory structures, which elucidate the visited solutions .If a potential solution has been already visited within a certain short-term period or if it has already violated a rule, it is marked as "tabu" (forbidden) so that the algorithm would not reconsider that possibility.

1) Arbitrarily develop an initial solution
2) Calculate neighbourhood
3) Choose a candidate move
4) Is candidate tabu? If yes then go to step 4a or go to step 5
   4a. Will solution be the absolute best? Or go to step 4b
   4b. Reject candidate move and adjust the neighbourhood then go to step 3.
5) Update solution by incorporating the candidate move, set z value
6) Have we reached the stopping criteria?
   6a. if yes -Stop and report the best solution found during search
   6b. if no – go to step 2.

Tabu Search Algorithm

Step 1. Let S be the preliminary feasible solution and Z its objective function value; then, set S* = S,
Z* = Z, max short-term memory (STM) = 5, and max iteration = 1,000; iter = 1. Best O value = O value.
Step 2. Arbitrary (i, j) = rand/Long-term memory (LTM) (i, j), (n1, n2) = the indices of maximum value in arbitrary.
Step 3. If there is none (n1, n2) in STM matrix, alter n1 and n2 locations; or else, repeat step 2.

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Step 4. Inset n1 and n2 in STM and release the last indices from STM (e.g., m1, m2); and LTM (m1, m2) = LTM (m1, m2) + 1.
Step 5. Compute the objective function value (Z) of the new permutation.
Step 6. If Z ≤ Z*, then Z* = Z, S* = S, and iter = iter + 1.
Step 7. If iter ≤ max iteration, then replicate step 2; or else, print Z* and S*.

4. Simulated Annealing

Simulated annealing (SA) is a standard probabilistic metaheuristic for combinatorial optimization problem of locating a good guesstimate to the global optimum of a given function in an attractive great exploration space. For certain problems, SA may be more efficient than exhaustive enumeration rather than the best possible solution. Paul et al [13] reported that for a number of varied problem instances, SA could perform better for higher quality targets while TS performs better for lower quality targets.

1) Set initial temperature; arbitrarily develop an initial solution
2) Arbitrarily choose unit and period of harvest to change in current solution
3) Is proposed solution better than current solution?
   3a. If yes- Then iterations = iterations + 1; total iterations = total iterations + 1
   3b. If no- then Calculate acceptance value- if solution accepted, Then move to step 3a or go to step 2.
4) Current solution = proposed solution
5) Is Time to change temperature?
   5a. if yes then -New temperature = old temperature x temperature reduction factor
   5b. if no then go to step - 2
6) Have we reached the stopping criteria?
   6a. if yes - Stop and report the best solution found during search
   6b. if no – go to step 2

Simulated annealing algorithm
S ← Create Initial Solution ( )
T ← T_0
While end conditions not met **do**
s' ← Pick At Arbitrary (N(s))
if (f (s') < f (s)) **then**
$s \leftarrow s'$
Else
Admit s' as new-fangled solution with possibility p (T,s', s)
End if
Modernize (T)
End while

5. Hybridized Tabu Search – Simulated Annealing Algorithm for Solving Optimal Reactive Power Problem

Both the simulated annealing and tabu search algorithms has been hybridized. Step 1 to step 6 main part of hybridization to handle the reactive power problem.

step1:
Set S as preliminary solution and z- evaluate objective function
step1. 3: S*=S and Z*=Z;
STM=5;// max short-term memory
Max iteration=1000; iter=1; best value O = O value
step2: randomize
step2.1: for i =1 to n do
for j =1 to n do
ARBITRARY (i,j)=rand/LTM;
step2.2: (i,j) and(n1,n2)=index of (ARBITRARY ∈ STM);
step3: T=0;
for i=1 to size (STM,1) do
for j=1 to size (STM,2) do;
if((n1,n2)==STM(i,j))
T=1; reiterate Step 2
if(T=0)
{
temp=n1;
n1=n2;
n2=temp
}
Step 4:
m1=size (STM,1);
m2=size (STM,2);
(n1, n2) =STM (m1, m2);
LTM (m1, m2) =LTM(m1,m2)+1;
step5: z=calculate objective function;
step 6 :
if(z<=z*) ; z*=z
{
S*=S;
iter=iter+1
}
step7: if (iter<=max iteration) ; repeat step 2 ; else print z* and S*

6. Simulation Results

At first Improved Tabu Search (ITS) 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.

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The preliminary conditions for the IEEE-57 bus power system are given as follows:
P_{load} = 12.102 p.u. Q_{load} = 3.014 p.u.
The total initial generations and power losses are obtained as follows:
$\sum P_G$ = 12.408 p.u. $\sum Q_G$ = 3.3142 p.u.
P_{loss} = 0.25826 p.u. Q_{loss} = -1.2038 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	**ITS**
V1	1.1
V2	1.032
V3	1.036
V6	1.022
V8	1.020
V9	1.002
V12	1.010
Qc18	0.0660
Qc25	0.201
Qc53	0.0470
T4-18	1.000
T21-20	1.040
T24-25	0.862
T24-26	0.871
T7-29	1.054
T34-32	0.870
T11-41	1.010
T15-45	1.031

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T14-46	0.912
T10-51	1.022
T13-49	1.064
T11-43	0.912
T40-56	0.901
T39-57	0.952
T9-55	0.952

Table 3: Comparison results

S.No.	Optimization Algorithm	Finest Solution	Poorest Solution	Normal Solution
1	NLP [14]	0.25902	0.30854	0.27858
2	CGA [14]	0.25244	0.27507	0.26293
3	AGA [14]	0.24564	0.26671	0.25127
4	PSO-w [14]	0.24270	0.26152	0.24725
5	PSO-cf [14]	0.24280	0.26032	0.24698
6	CLPSO [14]	0.24515	0.24780	0.24673
7	SPSO-07 [14]	0.24430	0.25457	0.24752
8	L-DE [14]	0.27812	0.41909	0.33177
9	L-SACP-DE [14]	0.27915	0.36978	0.31032
10	L-SaDE [14]	0.24267	0.24391	0.24311
11	SOA [14]	0.24265	0.24280	0.24270
12	LM [15]	0.2484	0.2922	0.2641
13	MBEP1 [15]	0.2474	0.2848	0.2643
14	MBEP2 [15]	0.2482	0.283	0.2592
15	BES100 [15]	0.2438	0.263	0.2541
16	BES200 [15]	0.3417	0.2486	0.2443
17	Proposed ITS	0.22002	0.23004	0.22268

Then Improved Tabu Search (ITS) algorithm has been tested in standard IEEE 118-bus test system [16]. 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 Improved Tabu Search (ITS) algorithm in reducing the real power loss.

Table 5: Comparison results

Active power loss (MW)	BBO [17]	ILSBBO/ strategy1 [17]	ILSBBO/ strategy1 [17]	Proposed ITS
Min	128.77	126.98	124.78	108.48
Max	132.64	137.34	132.39	114.26
Average	130.21	130.37	129.22	110.84

7. Conclusion

In this paper, an Improved Tabu Search (ITS) algorithm has been successfully solved the optimal reactive power problem. Hybridization of these two algorithms improved the exploration & exploitation capabilities during the search. In order to evaluate the validity of the proposed Improved Tabu Search (ITS) algorithm, it has been tested on Standard IEEE 57,118 bus systems and simulation results reveal about the good performance of the proposed algorithm in reducing real power loss and voltage profiles are within the limits.

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