Reactive Power Optimization of Power Grid based on TTGA Hybrid Algorithm

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Abstract. A new hybrid algorithm named TTGA hybrid algorithm which means genetic and tabu hybrid algorithm (TGA) with optimized tent mapping is proposed in this paper, through the research of tabu search (TS), genetic algorithm (GA) and chaotic algorithm (COA)\cite{1}. Based on evolutionary group generated by GA, auxiliary group formed by optimized tent mapping are led into group through specific selection mechanism so that the group become more diverse and effective. And in the meanwhile the tabu list is used to add a memory so that a similarity judgment mechanism is set based on the same individuals among group which provides a basis for using the TS operator to realize local fine search, so the tabu search plays the role of avoiding roundabout. In the new algorithm the introduction of TS ensures the capacity of hill climbing and refined search while the diversity of population and the effectiveness of evolution is assured by the regularity and ergodicity of chaotic. In this paper GA, IGA and TGA and TTGA is used in reactive power optimization of power grid, the results show that TTGA has the best performance on convergence and overall search.

1. Introduction

Because of the ergodic, stochastic property and inherent order of chaos, chaotic sequences can be introduced into optimization problems by the means of carrier transform\cite{2}. The problem of reactive power optimization is nonlinear and includes both continuous and discrete variables so that the traditional optimal methods don’t work well. For the actual power system the solution space is huge and searching easily falls in the local best solution, but the chaotic sequences having the characteristics of ergodicity and non-respective can solve this matter. In the chaos optimize algorithm searching is based on the orbit of chaotic sequences which are sensitive to initial conditions, so it may take a very long time to find the better solution space if the initial search points and control parameters are unsuitable or search space is very large\cite{3}. In this paper chaotic sequences are introduced to form a auxiliary population to realize global search and overcome the stochasticity in GA.

The genetic algorithm (GA) with the advantages of global optimization, implicit concurrency and independence of initial states is commonly used in the reactive power optimization (RPO)\cite{4-6}. However, the problems of premature phenomenon and bad ability in local search cannot be solved well. And the tabu search algorithm (TS) with memory function has strong local search and hill climbing capability, which can overcome the above-mentioned problems of GA. The necessity and feasibility of combination of these two algorithms were discussed by Glover, the founder of TS\cite{7}. In the hybrid algorithm proposed in this paper the memory function and n-opt operation is introduced too,
so that the capacity of climbing hill can be enhanced while the diversity of population can be kept by auxiliary population.

2. Genetic/Tabu Search Hybrid Algorithm with Improved Tent Map
In the paper a new algorithm which is a genetic/tabu search hybrid algorithm with improved tent map is proposed. Improved GA is the main part of the hybrid algorithm, and the tabu list is used to add a memory so that a similarity judgment mechanism(SJM) is set based on the same individuals among populations which provides a basis for using the TS operator to realize local fine search, and then the climbing ability of algorithm is improved and calculation time is saved so it’s more conducive to the real-time calculation optimization. Moreover, the introduction of auxiliary individuals mechanism(IAIM) and the concept of mixed population are presented due to the improved tent map of which the values are equally distributed. Synchronism with the evolution of genetic population, the initial population of which the individuals distributed uniformly in the solution space and auxiliary population which can update the genetic population in order to produce mixed population with IAIM are formed by the means of the iteration of improved tent map. Thus, the regularity and ergodicity of chaotic can overcome the stochastic of GA meanwhile the diversity of population and the effectiveness of evolution is assured.

2.1 Populations
There are genetic population(GP, $n$ individuals) and auxiliary population(AP, $m$ individuals) generated by improved tent map, and they formed the enlarged population(EP, $n+m$ individuals). Based on EP the mixed population are produced through the introduction of AIM.

2.2 Tabulist and release standard
Genetic individuals would be determined if they are tabu or repeated with tabu list which stores previous populations. Firstly, fitness value of the individual will be directly assigned if it is the same to one individual in tabu list. And then program decides whether the individual is replaced by current best solution or stays on the base of release standard that is the fitness value of the individual is larger than the average fitness value of previous population. Meanwhile, the number of the same individuals between current population and previous population is recorded. These operations can not only save calculation time, but also introduce memory function into search process which make circuitous routes in search be avoided. Moreover, an indicator of population diversity(SJM) is provided based on the number of the same individuals so that TS operators( enlarged neighborhood function) can be used when it’s necessary.

2.3 Similarity judgment mechanism(SJM)
According to the comparison for current and previous populations, three SIMs are set up as follows:

1. SJM1. The number of the same individuals between current population and previous population reaches to specified value $sameN$ in $sameG$ generations, or current best solution remains the same for specified value $bestN$.

2. SJM2. The number of the same individuals between current population and previous population reaches to specified value $sameN$ in $sameG$ generations.

3. SJM3. The current best solution remains the same for specified number $bestN$.

4. Based on SJM, TS operators and high mutating rate are used with the maximum number of high mutating rate iterations($maxM$).

2.4 Introduction of auxiliary individuals mechanism(IAIM)
The auxiliary individuals are generated by improved tent map so that mixed population are formed through IAIM in every generation, and then the evolution continues. The specific steps are as follows:

1. Calculate the fitness value of individuals in genetic and auxiliary populations, and sort them by fitness values separately.
(2) Compare fitness values of individuals between auxiliary and genetic population in order of lowest to highest. When the fitness value of auxiliary individual is higher than that of genetic individual, the genetic individual is replaced by the auxiliary individual, otherwise continue the comparison using the next auxiliary and the present genetic individual with the above replacing rule. This process continues until all of the auxiliary individuals take part in the comparison.

The process of genetic/tabu search hybrid algorithm with improved tent map is illustrated in Figure 1.

**Figure 1.** Flow chart of hybrid algorithm
3. Application and Analysis

3.1 Basic optimization techniques

Power flow calculation methods and optimization models are the basis of reactive power optimization. In this paper, considering the situation of the local power grid that there are lots of PQ nodes and value of R/X is high while it has uneven distribution of self-powered and long power distances which lead to high transmission loss and different voltage levels, so the Newton-Raphson method based on rectangular coordinate current influx and classical optimization model which contains the optimized target of transmission loss, voltage and reactive power limit are selected as the basic optimization techniques. The optimization model is as follows.

\[
F = \min[W_1 P_0 + W_2 \sum (\frac{\Delta U_i}{U_{i \max} - U_{i \min}})^2 + W_3 \sum (\frac{\Delta Q}{Q_{i \max} - Q_{i \min}})^2]
\]

\[\Delta U_i = \begin{cases} 
U_{i \max} - U_i & (U_i > U_{i \max}) \\
0 & (U_{i \min} < U_i < U_{i \max}) \\
U_{i \min} - U_i & (U_i < U_{i \min})
\end{cases}\]

\[\Delta Q_i = \begin{cases} 
Q_{i \max} - L & (Q_i > Q_{i \max}) \\
0 & (Q_{i \min} < Q_i < Q_{i \max}) \\
Q_{i \min} - L & (Q_i < Q_{i \min})
\end{cases}\]

Where \(W_1, W_2\) and \(W_3\) are the penalty factors of active power loss, voltage limit and generators reactive power constraint.

3.2 Optimization results

The voltage optimized range is set between 1.00p.u. to 1.07p.u. in accordance with “Guidelines on power system voltage and reactive power techniques(Trial Implementation)”(SD325-1989(2005)). The voltage of 110kV buses before and after the optimization is shown in Figure 2 and Figure 3. It can be seen from the below figure that the quality of voltage of 110kV buses is significantly improved. In both two operation modes the distributions of voltage concentrate to specified range, especially in operation mode 2 there are few buses of which the voltage are too high or too low.

**Figure 2.** The voltage condition comparison for operation mode 1

**Figure 3.** The voltage condition comparison for operation mode 2
3.3 Hybrid algorithms performance

GA, improved GA (IGA) in which adaptive crossover, mutation rates, different fitness functions and selective hybridization are introduced [8], genetic/tabu search hybrid algorithm (TGA) in which tube list and operators and SJMs are introduce based on IGA, and genetic/tabu search hybrid algorithm with improved tent map (TTGA) are applied to some local power grid respectively. Considering the randomness of evolution 12 times of iterations are taken and the optimization processes are analyzed as Figure 4 to Figure 6 and Table 1.

![Figure 4](image-url)  
**Figure 4.** Processes of optimizing by different algorithms (average performance)

![Figure 5](image-url)  
**Figure 5.** Processes of optimizing by different algorithms (best performance)

![Figure 6](image-url)  
**Figure 6.** Processes of optimizing by different algorithms (worst performance)

From Figure 4 to Figure 6 we can know that in reactive power optimization GA is easy to be trapped into local optimal solution while the other three algorithms continue searching. And TTGA has the highest and most stable speed of convergence and strongest capacity of hill climbing because of the introduction of TS and auxiliary populations formed by improved tent map which can ensure the global property of search and avoid premature phenomena in some degree.

**Table 1.** Average performance comparisons.

| Algorithm | Mathematical expectation | Variance($10^6$) | Average calculation time of fitness value of one individual(s) |
|-----------|--------------------------|------------------|---------------------------------------------------------------|
| GA        | 0.379930                 | 116.313          | 0.030289                                                      |
| IGA       | 0.406992                 | 11.80037         | 0.031580                                                      |
| TGA       | 0.407206                 | 6.753282         | 0.029822                                                      |
| TTGA      | 0.409853                 | 4.336612         | 0.024985                                                      |
From Table 1 it can be known that the solution gotten by TTGA is the best and the calculation time is saved for the direct assignment of the same individuals so that TTGA is more appropriate to be applied into the optimization of large system. What’s more, from the variances it can be seen that the randomness of TTGA is the lowest among four algorithms because of the regularity of chaotic sequences.

4. Conclusion
In this paper a new hybrid algorithm that is a genetic/tabu search hybrid algorithm with improved tent map is proposed through the research on the properties and hybrid strategies of GA, TS and COA. In the new algorithm the introduction of TS ensures the capacity of hill climbing and refined search while the diversity of population and the effectiveness of evolution is assured by the regularity and ergodicity of chaotic. Through the application in regional power grid it can be obviously seen that the hybrid algorithm we proposed has better ability of searching optima compared with GA, improved GA and GA/TS hybrid algorithm.

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