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Improved ant colony algorithm in the distribution of reactive power compensation device and optimization

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Abstract: Ant colony algorithm is a kind of simulation of collaborative optimization algorithm of ants foraging, imitating ants dependence information communication and social behavior, showing in the agents, on the basis of the definition of a greedy method under the guidance of the catalytic process guide each agent. Put forward improved ant colony algorithm is applied to power system of reactive power optimization, to IEEE14 node system by simulation calculation, the optimal scheme of reactive power compensation, the optimization design and improvement of ant colony algorithm of the optimization results can be more effectively at or near the optimal.

Keywords: Power˗ Ant colony algorithm ˗ Reactive power compensation ˗ Optimization ˗ Improved ant colony algorithm

1. introduction

In the electric power load distribution transformers, such as motor, most belonging to perceptual load, which need to consume large amounts of reactive power, long-distance transmission, increased power loss. In the power of installation shunt capacitor such reactive compensation device, can provide the perceptual load of reactive power consumed, namely the reactive power compensation. In China, the lowest level distribution network loss, universal, low voltage qualification rate, in such circumstances, the distribution of reactive power optimization research has important practical significance.

The ant colony algorithm (ACA) is put forward in recent years to a new kind of simulated evolutionary algorithm, and finally after multiple iterative approximation problem with maximum probability of optimal solution. Ant colony algorithm is parallel to the positive feedback algorithm, has stronger robustness, easily with other methods. Compared with other intelligent optimization algorithm has global searching capability, simple programming, but generally takes a long time, can use to search. Based on IEEE14 node as an experimental system simulation system, reactive power compensation devices to bring real utility to power supply departments of persuasive power of reactive power compensation with the work.

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2. Improvement of Ant Colony Algorithm

2.1 Ant Colony Algorithm

Ant colony algorithm is in the simulated annealing algorithm, tabu search algorithm and genetic algorithm, the artificial neural network algorithm and so on a series of heuristic search algorithm and an application of intelligent optimization problem in the heuristic random search algorithm, show in complex optimization problem of intelligent improved ant colony algorithm has a lot of advantages. Ant colony algorithm is based on the biological, when the ant search for food or in the nest in the path to the land, they left chemicals, namely, make certain information within the scope of the other ants can perceive and influence its behavior. When a path through the ant, leaving the pheromone more and more, so that the choice of the path of ants later higher probability, and increase the path to attract intensity, ant colony on the internal mechanism of formation of biological association, gradually formed a prior to their own unaware of the shortest route. Ant colony algorithm is required in each of the search space namely ant, an ant optimization function by a fitness value determined according to him, the ant is how much of the information surrounding the direction of their decision, ants and the road release information, to influence other ants.

2.2 Simple Ant Colony Algorithm

Consider target function: \( f_{\text{max}} = \max \{ f(x) | x \in B^L \} \), \( B^L = \{0,1\}^L \). Set t moments of ant colony \( A(t) = \{a_i(t), a_j(t), \ldots, a_k(t)\} \), \( a_k(t) \in B^L \), N for ant colony optimization scale definition, \( X_k(A(t)) = a_k(t) \). For \( x \in B^L \), the definition of \( x = 0, 1 (j \ j. j. - 1, \ldots) \), the scope for \( \{0,1\} \). Set information collection \( W(t) = \{w_{00}(t), w_{10}(t), \ldots, w_{i0}(t), \ldots, w_{0L-1}(t), w_{1L-1}(t)\} \), \( i = 0,1 \), \( j = 1,2 \ldots L - 1 \).

1) \( t = 0 \), constant;
2) For \( k = 1 \sim N \), \( j = 1 \sim L - 1 \), do \( r_j(a_j(t)) \), According to probability: \( P_{r_j}(t) = (1 - P_{\text{mut}}) \frac{(w_{0j}(t))^\eta (E_{0j})^\beta}{(w_{0j}(t))^\eta (E_{0j})^\beta + (w_{1j}(t))^\eta (E_{1j})^\beta + \frac{P_{\text{mut}}}{2}} \), Take it for \( 0,1 < P_{\text{mut}} < 1 \).

3) For \( i = 0 \sim 1, j = 0 \sim L - 1 \), \( a_i(t) = a_i(t), b \in \{0,1, \ldots, N\} \), \( w_{ij}(t) = w_{ij}(t)(1 - \eta), 0 < \eta < 1, \eta \) is attenuation coefficients.
4) For \( k = 1 \sim N, j = 0 \sim L - 1 \), \( w_{j(a_k(t))}(t+1) = w_{j(a_k(t))}(t) \delta / f(a_k(t)), \delta \) is constant.
5) to \( t = t + 1 \), if \( t \) meet beforehand, given the maximum number of iterative optimization is not clear when or \( f(a_k(t)) \) output current, the optimal solution \( a_k(t) \). Otherwise, to the second step.

2.3 Improved Ant Colony Optimization Algorithm

The ant colony algorithm and optimization process has three aspects: choice mechanism, update mechanisms and coordination mechanism. In the process of selecting mechanism, the ant colony algorithm through positive feedback optimal solution is the principle, strengthen if evolutionary eras to a certain degree, the premature stagnation phenomenon, and the optimal solution is local optimal. In the update mechanisms, most ant colony algorithms are neglected to understand.

In view of this, in the mathematical model of conventional by introducing "together" to measure the solution, thus even the strategy decision information updates every choice and the probability of path. If you have a test on the path of ants distribution is dispersive, together, thus difficult to strengthen lesser degree, so that the optimal information search slower, must strengthen the positive feedback information, make a few several excellent path with the larger probability is selected, when only the information updates, several more optimal path of information can get maximum enhanced. Conversely, when the test path when the ant on the distribution, large cluster degrees, causing premature and stagnation, intelligent optimization is to make solution, so you should let tend diversification of path has certain probability selected by dynamic adaptive, adjust and more information on the path is improved, and can effectively improve ant search speed of in the meantime also can avoid local optimization. Therefore, we
improved ant colony algorithm iterative process, the choice of the path for ants weight information according to the path of may gather to determine the degree, thus to determine the selected probability.

In the update process, improve the mechanism of ant colony algorithm based on information through the evenness of adaptive to update the information, the dynamic adjustment in the path of information distribution, unapt too centralized or dispersion, meanwhile enables convergence speed and prevent premature. Improved ant colony algorithm is based on the distribution of each path within the scope of the bad or good degree and constitute solution, dynamic update information weight information, a series of iterative calculation, and finally achieve information distribution, realize adaptive optimization of complex problems.

2.4 Improved ant colony algorithm of adaptive range

Improved ant colony algorithm of intelligent optimization thought through the path to measure the distribution uniformity information, we search process according to the ants were obtained in the distribution of the bad or good degree of reconciliation effectively adjust the route information updates strategy and the probability of path choice of ants, makes the ant colony algorithm convergence and stability are must improve convergence speed, and solved the premature stagnation phenomenon and the contradiction between the way, at the same time, the solution is more diversity, overall, suitable for large-scale complex problems.

3. Reactive power optimization model is established

Reactive power optimization model is a very complicated problem, main features are: nonlinear, discrete and large scale, the convergence of the initial dependence. To make the system network loss and node voltage offset, it must be combined minimum power reactive power optimization model of multi-objective in certain constraints. Accordingly, the reactive power optimization mathematical model should include object function, variable constraint equations and power constraint equations.

1) the objective function

The goal of the reactive power optimization, including economic goals and performance targets. The objective function is satisfaction to reactive satisfaction and overall satisfaction as voltage contents, comprehensive satisfaction as the objective function. In 1965 Harrington satisfaction functions, put forward the general thought is a response to all responsive variable synthesis in specific variables, and the function of each response under the satisfaction of values between 0 ~ 1, \[ d_Y(i = 1, 2, ..., r) \] with the increasing or decreasing the corresponding satisfaction, those \[ d_Y \] geometry average definition as much response system overall satisfaction, realizing the function of many response variables into single response variables, then a group of controllable variable portfolio X. Based on the synthesis of satisfaction:

\[
S = \alpha \sum_{j=1}^{N_{\max \text{Num}}} S_{t,j} + (1-\alpha)\sum_{i=1}^{N_{\text{th}}} S_{t,0} , S_{t,0} \text{ show voltage satisfaction with adjustable transformer (near the load side nodes)}, S_{t,0} \text{ show reactive power balance of satisfaction (except all nodes)}, 0 < \theta < 1, \text{the relationship of scale, satisfaction and reactive voltage (Voltage and reactive satisfaction), the satisfaction of actual application usually take 0.5}. \]

\[
S_{t,0} \text{ according to the following definition: } S_{t,0} = \begin{cases} 
1 & Q_{\text{min}} \leq Q \leq Q_{\text{max}} \\
1-0.6\times\frac{Q-Q_{\text{min}}}{Q_{\text{max}}-Q_{\text{min}}} & Q_{\text{min}} < Q < Q_{\text{max}} \\
0 & \text{else} 
\end{cases}
\]

\[ Q, Q_{\text{min}}, Q_{\text{max}} \] for i moment reactive power; \[ Q_{\text{min}}, Q_{\text{max}} \] is the minimum and maximum allowable reactive power. \[ Q \] is reactive expectations. We defined target function \( P = \beta S \), \( \beta \) is penalty. According to the definition of the
following ways: $\beta = \begin{cases} 1, & \text{Node voltage in qualified for 1, within the limits for when the node voltages for } \\ \epsilon, & \text{here } \epsilon \text{ is small positive. Here we take 0.000000001, in the limited power nodes, punish, correct results without effect.} \\
\end{cases}$

(2) Variable constraint equation

To make the safety of the electricity system operation, need certain constraints can guarantee, generally make power voltage of blast $V_{Gi}$, Reactive power compensation equipment capacity $Q_{Ci}$, adjustable transformer on-load tap positions $T_i$ as the control variables. Select node voltage amplitude $V_i$ and reactive power generators $Q_{Gi}$ as state variables. List inequality constraints: $V_{Gimin} \leq V_i \leq V_{Gimax}$, $T_{imin} \leq T_i \leq T_{imax}$, $Q_{Cimin} \leq Q_i \leq Q_{Cimax}$. Power voltage of blast upper and lower limits: $V_{Gimax}$, $V_{Gimin}$. Adjustable transformer on-load tap positions upper and lower limits: $T_{imax}$, $T_{imin}$. Reactive power compensation equipment capacity upper and lower limits: $Q_{Cimax}$, $Q_{Cimin}$.

State variable constraint inequality: $Q_{Gimin} \leq Q_i \leq Q_{Gimax}$, $V_{imin} \leq V_i \leq V_{imax}$. Node voltage amplitude upper and lower limits: $V_{imax}$, $V_{imin}$. Reactive power generators upper and lower limits: $Q_{Cimax}$, $Q_{Cimin}$.

(3) Power constraint equation:

$$P_i = \sum_{j \in H} V_j (G_{ij} \cos \theta_j + B_{ij} \sin \theta_j), Q_i = \sum_{j \in H} V_j (G_{ij} \sin \theta_j + B_{ij} \cos \theta_j),$$

$$P_{Gi} - P_i = 0, Q_{Gi} + Q_i - Q_{Ga} = 0.$$ In the equation $V_i, Q_i, P_i$ as node of voltage, $i$ injected into reactive and active; $\theta_i$ as node 1 and node $j$ voltage phase difference, $G_{ij}, B_{ij}$ as node admittance matrix elements of the imaginary part and real part. $H$ is directly connected with node $i$ all the nodes points.

4. Improved ant colony algorithm is applied to optimal distribution of reactive power compensation scheme

The improved ant colony algorithm is applied to reactive power optimization, need to have the following: the definition of adaptive ant colony, pheromones weight and transition probability, transfer strategy, adaptive pheromones and iterative end conditions.

4.1 The definition of adaptive ant colony optimization

(1) Gather degrees:

We have ants in $m$ only as $I$ starting $r$ path, the uniform distribution in every road is $m/r$ ant, we define the cluster nodes $i$: $jd(i) = \sqrt{\sum_{k=1}^{m} \left( \frac{m}{r} - a_k \right)^2}$, when $m$ ant focused on starting with nodes in the path of $r$ a certain,

the gather degrees in node $i$: $jd(i) = \sqrt{\sum_{k=1}^{m} \left( \frac{m}{r} \right)^2 + \left( \frac{m}{r} \right)^2} = m \sqrt{1 - \frac{1}{r}}$.

(2) Optional path:

For the gather degrees in node $i$ $jd(i)$ in the current node determine the ant choice of the path to step in, such as improved ant search speed can also avoid local optimization, take

$$pathselectnumber(i) = \left\lceil \frac{jd(i)}{max jd(i)} \cdot (r-1) + 0.5 \right\rceil + 1.$$

(3) Visit degrees:
Visit degrees expressed ant colony optimization path constraint, the rationalization of transfer in HengZuoBiao I can visit, including j expressed as
\[ \eta_{ij} = \frac{(r - |path(k, j) - j|)}{r} \]

4.2 Transition probability and pheromone weight

We have to start with I r path by pheromone strength, the serial order in stored in the array xinxisuorder, simply speaking, array xinxisuorder(j) element is the path (ij) to the value of the concentration of pheromone arranged serial number, pathselectnumber(i) is the path of pheromone strength arranged simply, the sequence of array element’s value set \( q = \frac{\text{pathselectnumber}(i)}{r} \) as
\[ e_{ij} = \begin{cases} q^{\text{xinxisuorder}(j)-1}, & \text{xinxisuorder}[j] \leq \text{pathselectnumber}(i) \\ 0, & \text{otherwise} \end{cases} \]
e_{ij} is the path (ij)’s pheromone weight. Rely on pheromone weight, the probability of ants under by node I choose node j.

\[ P_{ij}^k = \left\{ \begin{array}{ll} \frac{e_{ij}^{\tau^\alpha} \eta_{ij}^\beta}{\sum_{K \in \text{allowed}_k} e_{ij}^{\tau^\alpha} \eta_{ij}^\beta}, & j \in \text{allowed}_k \\ 0, & \text{otherwise} \end{array} \right. \]

4.3 Path transfer strategy:

Due to the convergence speed and the optimal solution of the problem, we put the adaptive factors in each time the ant transfer from distance, transfer, the volume is small points, whereas larger. Choose transfer points in probability of pos, last lastpos points for each step, the volume for: poschange = \( \begin{cases} 1, & \text{pos} \geq \text{lastpos} \\ -1, & \text{pos} < \text{lastpos} \end{cases} \), thus in the convergence speed and stagnation of balance, realize adaptive optimal selection of the path.

4.4 Adaptive pheromone refresh strategy and calculation method

Because information evenness can adaptively updated information, so can dynamically adjusting the path of information distribution, can accelerate convergence, and can avoid precocious, thus not overly dispersed or excessive concentration. According to the following strategy update information of the whole:

\[ \begin{align*} \tau_{ij}(t+1) = (1 - \rho)\tau_{ij}(t) + \sum_{i=1}^{m} \gamma_i \Delta \tau_{ij}(t) \\ \Delta \tau_{ij}(t) = \begin{cases} \frac{Q}{F_L}, & F_L \text{ is the } L \text{ ant the path length.} \\ 0, & \end{cases} \end{align*} \]

Ant colony algorithm (minimum value is, the paper distribution of reactive power optimization objective function is the maximum function. Thus we should ask the objective function is minimum mapping, so as to solve the problem of the optimization of reactive power compensation.

4.5 Iterative end conditions

In the cycle \( N_{\max} \), \( N < N_{\max} \) and \( 3/4 \) above the ants on a path, or when \( N = N_{\max} \) end the iteration.

Through the whole process from the start, a series of operations initialized to end, achieve optimal parameters, concrete process can participate.
5. Examples analysis

According to this reactive power optimization is based on improved ant colony algorithm, we IEEE14 according to the following steps to node simulation:

(1) the assumption of reactive power compensation devices on the entire network load node,
(2) give the disturbance, reactive power optimization scheme, reactive compensation device is prohibited.
(3) compared to the point where the action of reactive power compensation, by comparing the movement, the less node reactive power compensation devices,

If (4) in the current reactive compensation devices installed, under the site to step (2) continue,
(5) in steps (2), in a node in the restriction condition, voltage, immediately stop judging here should be installed reactive compensation devices. In step (3) process for the next few node, return to step (2). When all the voltage is the voltage disturbance condition, here permanently eliminate restricted node reactive power compensation devices installed.

(6) completed the circulation, get out successive optimal reactive power compensation equipment installation location.

Through simulation, the figure 2, reactive power compensation device at each node, the voltage fluctuation on expectations of 1.0 slightly, it explains in proper place installation reactive power compensation devices, according to improve quality of voltage distribution expectation, thus, method is feasible.
Figure 1. Improved ant colony algorithm reactive power optimization flow
Figure 2. Not have reactive compensation device voltage curve

Figure 3. Have reactive power compensation device voltage curve
6. conclusion

Based on a new intelligent optimization algorithm improved ant colony algorithm is used to optimize the reactive power compensation devices, established multi-objective nonlinear optimization model of reactive power, through the use of MATLAB language IEEE14 node system simulation, through the simulation diagram can see, this is based on improved ant colony algorithm of reactive power optimization allocation scheme can better determine the location of reactive power compensation devices, improved ant colony algorithm of general intelligent optimization algorithm is robust and higher in solving large-scale optimization problem, can have a better solution actual application prospect in the current distribution of reactive power compensation equipment installation, to study the optimization of reactive power compensation device configuration is of far-reaching significance.

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