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Research on Local Topology Intelligent Reconfiguration to Reduce the Operation Risk of Unban Power Network

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Abstract:

With the increasing scale of urban power network, higher requirements are put forward for improving power supply reliability and ensuring the safe and stable operation of power network. Various kinds of power network security work is also moving towards a more intelligent direction. In order to prevent the substation from losing voltage in the N-1 state, the identification method of the maximum possible transfer area, the power supply loop search method and the BPSO algorithm are proposed to reconfigure the local topology of the network. The validity of the proposed method is verified by the actual power network.

***Keywords**: unban power network, N-1 state, power loss of the substation, topology reconstruction, BPSO.*

I. INTRODUCTION

Due to the particularity of modern unban power network, accidents can quickly spread to the whole network. In 1998, the power failure of the business center in Auckland, New Zealand, led to a two-month power failure in 30 districts of the city center, with a direct economic loss of up to US $700 million; The "9.28" blackout in Italy immediately paralyzed the big cities and caused untold economic losses. Therefore, power system risk prevention is an important issue that must be considered in the development of power industry. Risk refers to the variation range and amplitude of potential loss. For the power grid, it is a combination of fault probability and impact. It should be able to identify the possibility of power grid failure events and the severity of the consequences of these events, so as to find a reasonable and economic measure to reduce the occurrence of high-risk failure events. Taking corresponding preventive measures before failure can avoid large-area power failure. Moreover, the unban power network has many standby lines, flexible structure, many topology combinations, convenient power grid control and easy reconstruction. Therefore, through the optimization and reconstruction of the unban power network topology, changing the power supply path of stations and loads, reducing the operation risk of unban power network, it is of great significance to improve the operation reliability of power grid.

Urban power network is different from transmission network. 220kV voltage level operates in ring network. 110kV voltage level is usually closed-loop design and open-loop operation, which is radial. Radiation network and ring network coexist in it. Moreover, there are many voltage levels, complex load types, different degrees of importance, and different requirements for power quality.

At present, scholars have done relevant research on risk-based urban power network research [1-3]. Literature [4] considers the natural and human factors causing operation risk, establishes a database of the relationship between typical faults and environmental scenarios, and realizes the online early warning of distribution network operation risk and risk level. Literature [5] considers the operation risk of N-1 accident during dispatching operation under the safe operation of power grid, establish the event probability model to evaluate the risk of N-1 event.There are three other risk-based unban power network research scenarios: one is to consider improving the self-healing ability of smart grid and reducing the power supply recovery time [6-10]; the other is to optimize the distribution network topology by considering the increase of network loss and voltage fluctuation caused by the large-scale access of distributed generation to the power grid and it's different deployment locations [11-16]; the other is to adjust the topology in order to solve the problems of equipment overload and transmission congestion [17-21].

There are three existing distribution network reconfiguration algorithms: one is mathematical optimization algorithm. Literature [22] proposed 0-1 integer programming method to solve distribution network reconfiguration to minimize system loss.One is heuristic algorithm, in which branch switching and optimal flow mode methods are used for distribution network reconfiguration [23-27]. These methods use the power loss variation of switching to find switches that need to be closed or disconnected. However, the optimization results largely depend on the initial structure of the network. In addition, the number of switches that need to be evaluated can be large. Therefore, the search efficiency is low and it is not easy to find the optimal solution. The other is artificial intelligence algorithm, such as particle swarm optimization algorithm [28-29], genetic algorithm [29-32], ant colony algorithm [33], tabu search algorithm [34], and harmonic search algorithm [35]. Generally speaking, this method can obtain the optimal solution. However, these methods are more susceptible to certain factors. For example, network size may make some parameters more difficult to determine.

Risk-based distribution network optimization research is mainly aimed at preventing N-1 or accidents in the power network under safe operation conditions. However, after N-1 accident check, there is almost no over-limit situation for line transmission power and node voltage after N-1 accident. However, in the N-1 state, there are already weak links in the power network to prevent N-1-1 events. Re-adjustment of the topology may result in the occurrence of current blockage or malfunction of protection devices in non-fault areas, so the optimal adjustment of the distribution network topology under risk conditions is worth studying.

This paper first analyzes the operational risk of distribution network and the optimization criteria to avoid the risk of voltage loss at the site. In order to improve the calculation speed, a region identification method based on the shortest power supply path is proposed, and a binary particle swarm optimization algorithm (BPSO) model is established to reduce the risk of substation voltage loss, which is used to solve the distribution network reconfiguration (DNR) problem. The validity of the proposed method is verified by an example of a regional urban power network.

II. RISK AVERSION TOPOLOGY OPTIMIZATION CRITERIA FOR UNBAN POWER NETWORK

The objectives and constraints of optimal preventive decision-making have changed in order to reduce the risk of voltage loss in substation. Therefore, the basic principles of optimization scheme need to be clarified first.

In urban power network operation, due to natural or man-made factors, transmission lines may be out of operation, transformer bus voltage loss and other risks may occur. When the risk occurs, it will cause load loss, serious substation voltage loss, causing a large area of power outage. Total station voltage loss is defined as total voltage loss of high voltage side buses of transformers in substations and no other power supply for the loads carried by the substations.

Fig.1 is a local urban power network topology structure in a region. The dashed line is a standby line. In normal operation, S2 station is supplied by S1 station and S3 station together, and 110kV substation is supplied by 220kV substation adjacent to each other. From the topology analysis in Fig.1, it is known that only one power supply supplies each 110kV substation, and the reliability of power supply is poor. In this case, the transmission line is disconnected from operation. It may cause the whole substation to lose voltage and cause serious load loss.

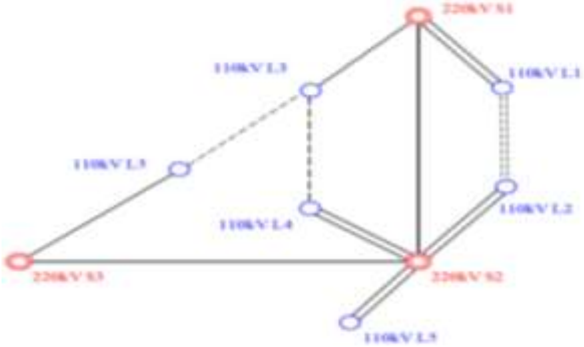

Fig. 1. Topology of local unban power network in a region

For the risk of voltage loss in substation, a criterion for topology optimization of urban power network is presented:

Criterion 1: In order to improve the reliability of power supply and reduce the risk of voltage loss in substations, each substation should ensure that there are two or more power sources in the whole station, and the substation can operate in split mode, such as two-split or Three-Split mode.

As shown in Fig. 2, 110kVS1 and S2 stations are separated into A and B stations, and the whole station is powered by two power sources, which improves the reliability of power supply.

Fig. 2. Schematic diagram of split operation of substation

When the S3-S2 line exits operation in Fig. 1, the S1-S2 transmission line is only supplied to the S2 station. If the S1-S2 line is disconnected due to a fault, the 220kV S2 substation becomes a decompression station. Therefore, when the S1-S2 line is supplied to the S2 station alone, it is necessary to consider transferring part of the load of the 110kV L2 and L4 substations under the S2 station from the nearby 220kV S1 substation with a power supply path.

Criterion 2: Loads that do not meet the transfer conditions shall be supplied by the adjacent 220kV substation to the local 110kV bus.

If the 110kV L5 station does not satisfy the transition conditions, its load should be considered to avoid the total station voltage loss when supplying the 110kV bus to L5 station and 220kV substation through the S1-L3-L4 line string for S2 substation.

Criterion 3: Avoid formation of electromagnetic loop network.

In the series supply scheme, the formation of electromagnetic ring network shall be avoided as far as possible. Therefore, it is necessary to cooperate with the bus tie circuit breaker of the substation and the line switch, and open the electromagnetic ring network by means of the mutual cooperation between the split operation of the substation and the on-off of the line.

III. URBAN GRID TOPOLOGY RECONFIGURATION MODEL

3.1. Objective function

According to the existing parameters of urban grid, by changing the status of line switches and bus tie circuit breaker of substations, the original distribution network can not only meet the requirements of operation constraints, but also reduce the risk of voltage loss in substations.

The grid risk of urban power network in operation includes the risk of voltage loss and load loss in single supply substation. In order to quantify the risk of voltage and load loss in substation, a score table for quantifying the effect of reconfiguration plan is built. The score table is shown in TABLE I and TABLE II.

TABLE I. Quantitative evaluation scores of loss load

	Level 5	Level 4	Level 3	Level 2	Level 1
Lost load (MW)	5-30	30-50	50-100	100-300	300
Deduction value	-10	-15	-20	-25	-30

TABLE II. Quantitative score of substation voltage loss number

	Level 4	Level 4	Level 4	Level 4
Substation voltage loss number	1*110kV stations	1*220kV station	(1-2)*220 kV stations	1*500kV station
		2*110kV stations	(3-7)*110 kV stations	4*More than 220kV stations
				7*More than 110kV stations
Deduction value	-15	-20	-25	-30

With the highest score as the objective function, the reconstructed model used in this paper is:

$$S=\exp(\mu_1 \ln\left(100+L_{CZ}\right)+\mu_2 \ln(100+L_{FH})) \qquad (1)$$

Where, L_{FH} is the deduction value for the loss of load and L_{CZ} is the deduction value for the number of voltage-losing substations. μ_1, μ_2 is the weight factor, which satisfies $\mu_1+\mu_2=1$, µ1 the larger the value of 1, the more attention is paid to the impact of the number of voltage-losing substations on the risk level.

The grid risk score of the scheme is based on the grading table of power safety events. A scoring system is built for the load reduction and the voltage loss of substations respectively. When calculating, the maximum deduction value is taken for the two scoring systems. For different N-1-1 events, the grid risk is evaluated comprehensively by calculating the mean of the risk score.

3.2. Operational constraints

After the objective function is established, the following constraints must also be met in the process of distribution network reconfiguration.

Equality constraints

The equality constraints are mainly power flow equation constraints.

$$\begin{cases} \Delta P = P_{Gi} - V_i \sum_{j=1}^{j=n} V_j \left(G_{ij} \cos\theta_{ij} + B_{ij} \sin\theta_{ij} \right) = 0 \\ \Delta Q = Q_{Gi} - V_i \sum_{j=1}^{j=n} V_j \left(G_{ij} \sin\theta_{ij} - B_{ij} \cos\theta_{ij} \right) = 0 \end{cases} \tag{2}$$

Where, P_{Gi} and Q_{Gi} respectively represent the active and reactive power injected by the ith node; Vi represents the voltage amplitude of the i^{th} node; G_{ij}, B_{ij} and θ_{ij} respectively represent the conductance, susceptance and voltage phase angle difference between two nodes i and j.

3.3. Inequality constraints

Inequality constraints mainly include node voltage constraints and branch current constraints.

$$U_{i\min} \le U_i \le U_{i\max} \tag{3}$$

$$I_{i\min} \le I_i \le I_{i\max} \tag{4}$$

U_i is the node i voltage, I_i is the transmission current value of branch i, U_{imin} and U_{imax} are the minimum and maximum allowable voltage of the node, and I_{imin} and I_{imax} are the minimum and maximum allowable transmission current of the line, respectively.

3.4. Reduce search space method

3.4.1. Identification method of maximum possible transfer area

When facing a large and complex urban power network, the total number of bus tie circuit breaker and outgoing switches will be thousands. If the whole network is reconstructed directly, the dimension of the solution will increase, and its search space will increase dramatically in geometric series.Take the IEEE-33 node for example, with a total of 37 switches, there are 237 combined states, and the data size is extremely large. However, there are a lot of infeasible solutions which do not satisfy the radial requirements, which not only greatly reduces the efficiency of algorithm optimization, but also affects the acquisition of optimal fitness values. Therefore, it is very important to solve the distribution network reconfiguration problem by simplifying the distribution network topology and reducing the search space with an appropriate search method.

For local risks, a method for identifying the region to which the maximum possibility is transferred is presented, which greatly reduces the set of switches to be searched for for dimensionality reduction.

(1) Close all the switches in the power grid, proceed from the voltage-losing risk bus, and conduct deep search until another 220kV substation's high-voltage bus is searched to obtain the set of switches contained in all possible power supply paths of the voltage-losing risk bus;

(2) Depth search is carried out from bus stations near 220kV substations that have been searched until new 220kV substations are encountered, and the shortest power supply path connected by 110kV substations is obtained;

(3) Combine the set of switches contained in the shortest power supply path with the set of switches in step 1 to obtain the total set of topological search switches.

The flow chart of identification method of maximum possible transfer area is shown in Fig. 3.

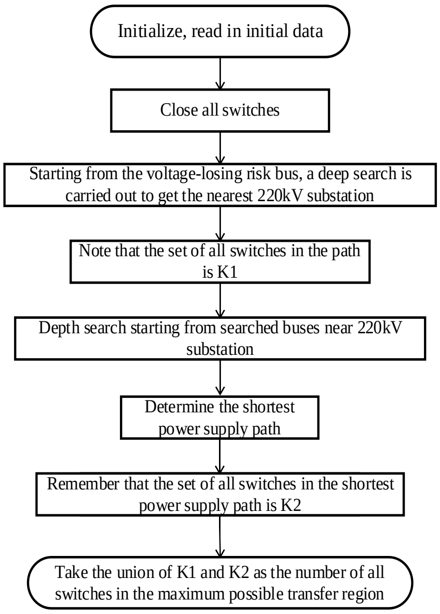

Fig. 3. Identification process of maximum possible transfer area

3.4.2. Determining basic loop group based on minimum spanning tree

Search space based on loop group search mode is determined by the number of branches of the basic loop group, and the selection of the basic loop group directly affects the scope of search space. Based on this, this paper presents a minimum spanning tree to determine the optimal basic loop group and complete the encoding of loops.

a) By closing all switches, an association matrix is generated. By using the correlation matrix, nodes with a node degree of 2 are merged, thus simplifying the topology to a weighted undirected graph of generalized branches with a weight value of the number of branches between the two nodes. From this, the adjacency matrix L, $L_{i,j}$ denotes the weight of i, j nodes, 0 denotes no connection;

b) Disconnect all switches and generate a minimum spanning tree based on the adjacency matrix. Connections are added from small to large weights, and the resulting loop is the minimum basic loop. Complete encoding of basic loop groups until maximum weights are added.

IV. BPSO SOLVING TOPOLOGY RECONSTRUCTION PROBLEM

4.1. BPSO algorithm

Particle swarm optimization (PSO) algorithm was originally proposed to solve spatially continuous optimization problems. It is an iterative-based multipoint random search optimization algorithm. When solving practical optimization problems, each particle corresponds to a solution and carries information about location, speed, fitness value, individual optimum, and global optimum. Moving a particle to an optimal solution by iteratively updating its position and velocity.

In order to deal with the discretization problem, Dr. Kennedy and Dr. Eberhart proposed BPSO (Discrete Binary Particle Swarm Optimization Algorithm). Binary particle swarm optimization algorithm uses binary coding form. The corresponding position of each particle is written into a certain dimension, and its meaning of each dimension is 0 or 1. The new meaning of particle velocity is the probability of particle position change. The particle velocity constraint function Sigmoid is limited to the region [0,1]. The rules for iterative updating of the velocity and position of BPSO particles are as follows:

$$\begin{cases} v_{i,d}^{k+1} = \omega v_{i,d}^{k} + c_1 r_1^{k}\left(p_{besti,d}^{k} - x_{i,d}^{k}\right) + c_2 r_2^{k}\left(g_{besti,d}^{k} - x_{i,d}^{k}\right) \\ x_{i,d}^{k+1} = x_{i,d}^{k} + v_{i,d}^{k+1} \\ Sigmoid\left(v_{i,d}\right) = 1/\left(1 + e^{-v_{i,d}}\right) \end{cases} \tag{5}$$

Where, ω, c_1 and c_2 are system parameters, which are inertial weights and learning factors respectively. r_1^k, r_2^k are random numbers between [0,1] generated by MATLAB; Represents the velocity and location information of the first particle in the d-dimensional space, respectively; $p_{besti,d}^{k}$ and $g_{besti,d}^{k}$ represent the individual optimal locations of the i^{th} particle found in the previous k generation and the overall optimal locations of all particles found in the previous k generation, respectively.

The particle's velocity determines the probability of 0 or 1 being removed from the point location. If the particle velocity randomly generated by the system is less than $Sigmoid$ (v_i,d), then $x_{i,d}$=1 and vice versa, $x_{i,d}$=0.

The switch of distribution network only has two states: on and off, so binary PSO is more suitable.Each particle represents a combination of switch states, which adopts binary coding. 0 indicates that the switch corresponding to this bit is open and 1 indicates that the switch corresponding to this bit is closed.

4.2. Update strategy of ring division substitution

Combining the characteristics of the maximum possible transfer region and BPSO, an update strategy of loop-by-loop substitution is proposed, which can further optimize the update and generation of new particles, and make the optimization process more specific and efficient.

The BPSO iteration process produces an global optimal $g_{best}(x_1,x_2,\ldots, x_n)$ with a set of disconnected switches $g_k(k_1,k_2,\ldots,k_m)$, where $(k_1,k_2,\ldots,k_m)$ are the disconnected switches in each power supply path $(L_1,L_2,\ldots,L_m)$. In the next iteration, the particle velocity in BPSO is transformed into position information via the Sigmoid function, which is equivalent to the probability of switch interruption.

The alternative switch $p_k(p_{k1},p_{k2},\ldots,p_{kt})$ is the t switches with the highest interruption probability in each power supply path, which is replaced with the corresponding elements in the corresponding path of $g_k(k_1,k_2,\ldots,k_m)$.Only one loop is changed at a time, and the break switches of the remaining loops still use the switches in $g_k(k_1,k_2,\ldots,k_m)$.In the replacement of the second loop, the switches in bk are used to replace the k_i in $g_k(k_1,k_2,\ldots,k_m)$ one by one. If the pk replacement of the alternative switch meets the radiation requirements, then the power flow is calculated and the loss load and the number of total station voltage-losing substations are recorded. If not, the loss load is inf, which is assumed to be infinite. After the substitution of alternative switches for the first route, the number of loss loads and total station voltage-losing substations in these combinations are compared, the minimum value of loss loads and their corresponding solutions are recorded, and the minimum value of loss loads is made full use of the data to update the global optimum and improve efficiency in the later iteration period. The alternate switch corresponding to the minimum loss load is recorded as k. After replacing all loops, the state $g_{kai}(k_1^{'},k_2^{'},k_3^{'},...,k_{m-1}^{'},k_m^{'})$ of the next generation of updated particles is obtained.

V. CASE STUDIES

In order to verify the effectiveness of the method proposed in this paper, a regional unban power network is taken as an example system, as shown in Fig. 4. The solid line in the figure is the actual operation transmission line, the dotted line is the standby transmission line, the red line is the 220kV voltage level, and the blue line is the 110kV voltage level. The system includes 66 220kV substations and 232 110kV substations, with a total load of (8143.5 + j2221.4) MVA.

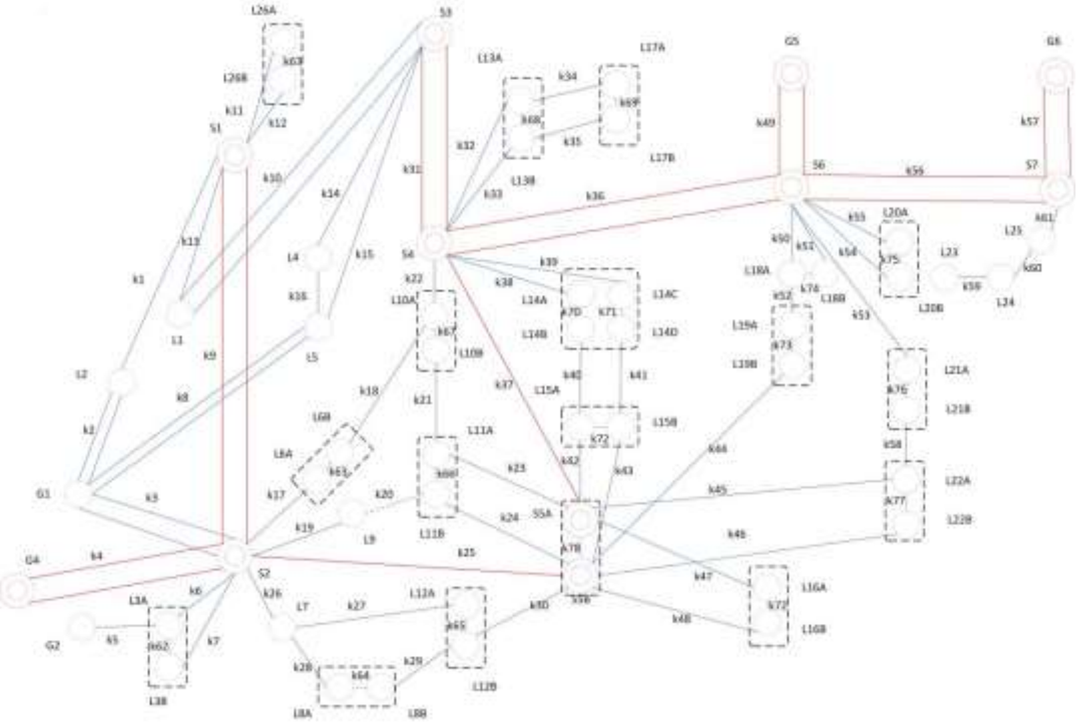

Fig. 4. Topology of local power grid in a region

5.1. Search space

Based on the looping group search method and through the minimum spanning tree, the 33-node basic looping group generated is $S(S_1,S_2,S_3,S_4,S_5,S_6)$. Specifically as follows:

$$\begin{cases} S_1 = [k_{42}, k_{40}, k_{70}, k_{38}, k_{37}] \\ S_2 = [k_{43}, k_{41}, k_{71}, k_{39}, k_{37}] \\ S_3 = [k_{37}, k_{22}, k_{67}, k_{21}, k_{23}] \\ S_4 = [k_{45}, k_{58}, k_{76}, k_{53}, k_{36}, k_{37}] \\ S_5 = [k_{46}, k_{77}, k_{58}, k_{76}, k_{53}, k_{36}, k_{37}] \\ S_6 = [k_{24}, k_{20}, k_{19}, k_{25}] \end{cases} \tag{6}$$

5.2. Analysis of optimization results

During normal operation of unban power network, 220kV S2-S5 line tripping occurs, which causes S5 stations to be supplied by S4 stations alone, and causes the risk of voltage loss in S5 stations. That is, if the 220kV S4-S5A line tripping continues, it will result in voltage loss in 220kV S5 stations, 110kV L15 stations, L19 stations, L16 stations, L22 stations, L8B stations, L11 stations and L12B stations, and loss of load 221.021MW, resulting in level 2 events.

As shown in Fig. 4, 220kV S2, S4 and S6 stations can be used as power supply for 110kV substations (such as 110kV L16, L11, L15, L19, L22, L12, etc.) under S5 and S5 stations when the risk of total station voltage loss exists at 220kV S5 stations.

Scanning the S5 peripheral topology in depth and width, a total of 80 optimizable switches were obtained. TABLE III shows a partial set of switches for a topology optimization region.

TABLE III. Topology optimization area switch set (part)

Line switch			
Switch name	Switch status	Switch name	Switch status
k30	on	k38	on
k23	on	k22	on
k42	on	k52	on
k43	on	k27	on
k46	on	k46	on
k45	on	k18	on

As can be seen from TABLE IV, if serious events occur in the local area after reconstructing the algorithm in this paper, that is, S4-S5A Line exits operation, and the voltage-losing yards and loads are as shown in TABLE V.

TABLE IV. Topology optimization scheme

Line name	Switch status	Topology change after action
k76	off → on	L22a and l21b go to S6 station
k45	on → off	
k67	off → on	L11a to S4 station
k23	on → off	
k70	off → on	S4 station provides 110kV bus of S5 station in series for the load of S5 station, L16 station and l11b station

TABLE V. Voltage loss station and load statistics

Voltage loss substation	Lost load (MW)
L22B	15.06
L19B	35.8
L12B	5.202
L8B	4.4
Total 60.46MW (level 3 event)	

After the adjustment of search and optimization, the risk level of the event is reduced from the second level to the third level event, with a scheme score of 91.46 points, the loss load is reduced by 156.501MW compared with that without topological reconfiguration, and there is no total station voltage loss and line transmission current overload, so as to reduce the risk level of operation.

5.3. Multi-time interruption optimized plan comparison

To further consider the validity of the proposed methods under multi-time sections, the same initial N-1 settings (220kV S2-S5 trips) and optimal plan generation were performed on the power grid at 20:00 on October 15th, 10:00 on October 18th, 9:00 and 14:00 on October 19th, 2021, respectively, due to the differences between the operation modes of the power grid at the above four sections and at 10:00 on April 26th, 2021. The total loads of the power network at 9:00 and 14:00 on October 19th, 2021 are 5204MW and 5442.5MW, which are lighter. The total loads of the power network at 10:00 on October 18, 2021 and 20:00 on October 15, 2021 are 6850MW and 6957MW, respectively. The loads are heavier, so the predictions obtained by the search have changed.

There is a transfer and a series supply scheme for 110kV L22 station:

Transfer scheme: transfer L22A to S6 station. At this time, if S6-L21A line is returned, L21 station and L22A station will be lost.

Serial supply scheme: through S4-L14-L15-S5 series for L22A and L21B stations. Lines S4-L14C and L14D-L15B are overloaded after serial donation (Line S4-L14C is overloaded 45.5A), but there is no risk of losing pressure at station L21.

5.3.1. Time section with serial supply scheme for L21 station

At 9:00 on October 19, 2021, the optimized plan obtained by the search is shown in TABLE VI, and there is no overload of the serial supply scheme at this time.

TABLE VI. Reconstruction plan at 9:00 on October 19, 2021

Line name	Switch status	Topology change after action
k78	off → on	S4 for S5 whole station
k21	off → on	L11a to S4 station
k23	on → off	
k20	off → on	L11b to S2 station
k24	on → off	

k70	off → on	S4 station supplies 110kv1m bus of S5 station in series to ensure 10kV load of S5 station, and supplies deep l16a, l22a and l21b in series

At 14:00 on October 19, 2021, the optimization plan obtained after search is shown in TABLE VII.

TABLE VII. Optimization plan at 14:00 on October 19, 2021

Line name	Switch status	Topology change after action
k78	off → on	S4 for S5 whole station
k21	off → on	L11a to S4 station
k23	on → off	
k70	off → on	S4 station supplies 110kv1m bus of S5 station in series to ensure 10kV load of S5 station, and supplies deep l16a, l22a and l21b in series

In this case, the scheme of series feeding large-impact station is adopted, S4-L14A and L14B-L15A are overloaded, and the maximum overload current is 231.4A.

To eliminate overload, S5A-L12B and S5A-L11A are transferred to 110kV bus 1M of S5 station, 6.8MW load of L15 station is transferred to S4 station via S4-L14C line, and the overload is eliminated after transfer.

5.3.2. Time section that can be transferred to L22 station

At 10:00 on October 18, 2021, and 20:00 on October 15, 2021, the optimized plans obtained by the search are as follows: TABLE VIII, with no overload.

TABLE VIII. Reconstruction plan at 10:00 on October 18, 2021 and 20:00 on October 15, 2021

Line name	Switch status	Topology change after action
k78	off → on	S4 for S5 whole station
k21	off → on	L11a to S4 station
k23	on → off	
k20	off → on	L11b to S2 station
k24	on → off	
k76	off → on	L22a to S6 station
k45	on → off	
k70	off → on	S4 station supplies 110kv1m bus of S5 station in series to ensure 10kV load of S5 station, and supplies deep l16a, l22a and l21b in series

If the scheme of serial feeding L22 station is adopted at this time, the S4-L14C line and L14D-L15B line are overloaded, and the maximum overload current at two time sections is 147.9A and 201.4A, respectively.

To eliminate the overload, the S5A-L12B is transferred to S5B, and there is still line overload in the two sections after the transfer. The maximum overload current is 45.5A and 166.7A, respectively. That is, at this point only a diversion scheme is available.

5.4. Optimization efficiency

In order to compare the outstanding points of this algorithm in optimization efficiency, it is necessary to compare the total number of power flow calculations performed during the reconstruction process. Without a specific coding strategy, the total number of general tide calculations is equal to the product of the initial population size and the average number of iterations. When the search success rates are similar, the fewer power flow calculations, the more efficient the algorithm will be. TABLE IX shows the comparison of some intelligent algorithms in search efficiency.

TABLE IX. Comparison of optimization efficiency of different algorithms

Algorithm category	Initial population size	Average iterated algebra	Power flow calculation times
BPSO + traditional coding	50	24.68	1235
Clonal genetic + ant colony algorithm	50	41.5	2075
Ant colony	15	About 69	1035
Immune BPSO	100	9.03	903
Fuzzy genetic algorithm	50	33.5	1675
Paper algorithm	15	2.32	828

As shown in Table 9, when solving distribution network with BPSO algorithm, this paper calculates power flow much less often based on looping group search and looping substitution update strategy than traditional coding. From an average of more than 1235 times to an average of 828 times, the efficiency is improved by 67%, which fully demonstrates the superiority of the optimization efficiency of this algorithm. Looking at the number of flow calculations for each refactoring document listed in Table 9, the total number of flow calculations for general algorithms is higher than 1000, and the optimization efficiency value is not high. The algorithm presented in this paper is only about 828 times. Except for the updates of particle velocity and location information, it does not involve any other calculation and has obvious advantages in search efficiency.

VI. CONCLUSIONS

According to the topology characteristics of unban power network, this paper puts forward the risk aversion topology optimization criteria for urban power network and BPSO solution for DNR problem by substituting ring renewal strategy. Taking an actual power network in a certain area as an example, through the simulation and validation of the power network with different time sections, it is shown that the search method and the renewal strategy algorithm of loop substitution proposed in this paper can effectively reduce the failure level of N-1-1 events around S5 station, and different optimization schemes can be put forward according to the operation mode of different time sections to meet the requirements of power network operation. Search space has been reduced from 278 to 21000 combinations, which has a prominent performance in reducing search space and reducing the risk of voltage loss in substations. The average number of optimal power flow searches has been reduced from about 1000 times to 828 times compared with the general algorithm, and the optimization efficiency is high.

In the follow-up research, according to the strict requirements of power grid dispatching operation, the current urban power grid reconstruction plan also needs to consider the generation of switching action operation sequence and the mathematical expression of more stringent constraints of power grid radiation requirements.

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