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Mathematical model for rapid reconstruction of regional power grid based on 0-1 nonlinear programming

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ABSTRACT. *Based on the actual work content of regional power grid control center, combined with mathematical optimization theory, a mathematical model of regional power grid reconstruction based on 0-1 nonlinear programming is proposed. The model takes the minimum value of the state change of the transmission line of the whole network as the objective function, and advocates to adjust the operation mode of the grid under different conditions in the shortest time. Constraints include 220kV substation main transformer load and 110kV transmission line current carrying capacity (mainly directly connected to 220kV substation) within the specified range, 110kV network radiated power supply, there is no power supply island in the network. Constraints not covered in the model, such as 220kV flow section and voltage, will be verified in the next step using the PSASP synthesis program.*

KEYWORDS: *regional power grid; 0-1 nonlinear programming; power grid reconstruction*

1. Introduction

At present, research on grid reconfiguration is mostly directed at 10kV distribution networks, while 110kV regional-level grid reconfiguration is rarely seen. Network reconfiguration changes the network structure and operation mode by changing the state of the switch, reducing network loss and improving operational reliability [1]. When the line switch status changes, the power supply architecture of the feeder can be reassembled, the load transfer of the feeder and the main transformer can be performed, and part of the load of the overload feeder can be appropriately transferred to the light load feeder to relieve the system overload problem and increase the overload transformer and The capacity margin of the feeder.

There are many constraints on load transfer, such as main transformer, allowable current of feeder; voltage pass rate; no power failure and power change; ensure that the phase sequence on both sides of the tie switch is consistent, the voltage difference is not more than 7%, and the phase difference is not more than 10 degrees. The time of load transfer and so on. In practical applications, grid reconfiguration is actually a problem of searching for the optimal operation mode of the grid [2].

Due to the nonlinear characteristics of power grid reconstruction, each power flow calculation needs to be performed once for each optimization iteration. Continuous power flow calculation requires a large amount of calculation time. In order to improve the calculation speed, in the research of distribution network reconfiguration, researchers have tried many different algorithms to solve the problem of grid reconfiguration. At present, the main commonly used are: mathematical optimization theory [3], optimal flow mode method [4], branch exchange method [5] and artificial intelligence method [6].

In order to combine the advantages of mathematical optimization theory and PSASP synthesis program, using mathematical optimization model, several optimal and suboptimal solutions are obtained at one time under less constraints, and then PSASP is called to perform power flow, voltage and other constraint verification, and finally obtain a Comprehensive optimal solution[7-11].

Based on the actual work content of the regional power grid control center, this paper focuses on how to obtain the reasonable operation mode that meets the constraints with the least change of line state. Combined with the mathematical optimization theory, the preliminary regional level based on 0-1 nonlinear programming is proposed. Mathematical model of grid reconstruction. Constraints not covered in the model, such as 220kV flow section and voltage, will be verified in the next step using the PSASP synthesis program.

2. Regional power grid mode status

As the power grid operation headquarters, the power regulation department plays a decisive role in the safe and reliable operation of the power grid. In addition to ensuring the real-time stable operation of the power grid, the control center must also combine the development of the power grid and the growth of load demand, and reasonably formulate the operation mode of the power grid under different loads in the future. For a regional power grid, the mode arrangement mainly involves the following three aspects:

2.1 Daily maintenance of the power grid

During the operation of the power grid, equipment is inevitably subject to insulation aging, faults, etc., and daily maintenance can prevent problems before they occur and reduce the incidence of failures. In order to ensure the safety of maintenance personnel, power grid construction areas are generally required to be powered off. This requires the control center to formulate a reasonable control plan, transfer the relevant load through the switching operation, and make the flow section meet the requirements.

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2.2 Self-propelled action when the grid is faulty

Most of the regional power grids are centered on large cities. Due to the high land price, the substation construction adopts the same tower parallel or multi-cable and same trench method. Once a tower accident or cable fire occurs, the entire substation may lose pressure. The load needs to be transferred to other substations in the shortest time while ensuring the stability of the grid. This requires the control center to formulate a corresponding self-injection action plan in time to minimize losses.

2.3 Operation mode under different loads in different periods

Generally speaking, the peak of electricity consumption appears in the winter and summer seasons. When the control center arranges the next year's operation mode, it mainly refers to the power grid construction and the large load and small load forecast values in winter and summer. For regional power grids dominated by hydropower, power generation during the wet and dry periods should also be considered.

The arrangement of the above three aspects can be divided into two categories, one is the real-time mode arrangement of the power grid, and the other is the future mode arrangement of the power grid. For the real-time mode arrangement, in order to avoid local area lines and main transformer heavy load or overload, the power grid dispatch control staff generally formulates corresponding control measures in time according to the operational monitoring data of important power flow sections in the power grid. The staff involved in the development of the scheduling plan requires extensive work experience and decision-making ability. This type of work relies heavily on manual judgment, is inefficient, and has high risks, and it is difficult to ensure its effectiveness when the problem is complicated. Moreover, when a major accident occurs, such as a 220kV substation full station loss of pressure, the preparation of the action plan needs to be determined in a very short time, only by manual decision, it may be difficult to deal with. For the future mode arrangement, due to the uncertainty of the construction of the power grid, the uncertainty of the operation time and the uncertainty of the predicted load data, there may be repeated developments, which greatly increases the workload of the moderators.

3. Mathematical model

Distribution network reconfiguration is mostly aimed at reducing network loss, balancing load and improving supply voltage quality. The same is true for 110kV regional power grid reconstruction. In addition, according to the production needs of the power control center, minimizing the number of contact switches and segmentation switches has also become one of the optimization goals. The low number of switching operations can save a lot of switching operation time, so that the power grid can be reconstructed as soon as possible to improve the quality of power supply. In the process of power grid reconstruction, it is necessary to continuously verify the characteristics of the power flow section, voltage qualification rate, main

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transformer load, and line thermal stability. The 110kV power grid should also meet the radiation power supply to avoid the formation of islands.It can be seen from the above analysis that 110kV regional power grid reconstruction is a multi-objective nonlinear optimization problem. In general, in order to reduce the difficulty of solving and the time of calculation, multi-objective planning will be transformed into single-objective programming. Considering the demand of the dispatching work, a stable operation mode is obtained with fewer switching operations, and the switching operation is finally manifested in the change of the state of the transmission line. In order to reduce the function variable, the target of "the minimum amount of state change of the transmission line of the entire network" is targeted. The function transforms the multi-objective problem into a single-objective problem, and obtains the mathematical model of grid reconstruction based on 0-1 nonlinear programming.

Taking "the minimum change of state of the transmission line of the whole network" as the objective function, the constraints include: 220kV substation main transformer load and 110kV transmission line current capacity (mainly directly connected to 220kV substation) within the specified range, 110kV network radiation power supply There is no power island in the network. The corresponding mathematical model is obtained as shown in equations (1) to (4).

$$\min \sum_{i=1, j=1}^{k} \left| K_{ij} - \left(K_{ij}\right)_0 \right| / 2 \tag{1}$$

$$st. \sum_{m} \left(\sum_{LJ} \prod K_{ij}^{(m)(n)} \cdot P^{(m)} \right) < S_n \tag{2}$$

$$\sum_{m} \prod K_{ij}^{(l)} \cdot P^{(m)} \le S_l \tag{3}$$

$$\sum_{LJ} \prod K_{ij}^{(m)} = 1 \tag{4}$$

K_{ij} —Line state between substation i and j, 0 means power failure, 1 means power transmission, Kii=0;

$\left(K_{ij}\right)_0$ —The initial operating state of the line between substations i and j;

$P^{(m)}$ —110kV substation m with load;

S_n —The maximum capacity that the main transformer of the 220kV substation can withstand;

S_l —Line l satisfies the maximum power that can be delivered under thermal stability conditions;

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LJ—All power supply paths for the 110kV substation m.

Equation (2) corresponds to the 220kV substation main transformer load is reasonable, the formula (3) corresponds to the line current carrying capacity is reasonable, that is, to meet the thermal stability conditions, the formula (3) corresponds to the network radiated power supply and there is no power supply island. So far, the 110kV regional power grid reconstruction problem has been successfully described by mathematical models.

4. Model solving

In order to illustrate the applicability of the mathematical model, the 20-node network shown in Figure 1 is constructed, and its optimization is reconstructed in different situations by using equations (1)~(4), which are mainly divided into three aspects: (1)14 Modes for the power failure and maintenance of No. 9 and No. 9 lines; (2) Arrangement for the main transformer overload of No. 2 220kV substation; (3) Arrangement for the increase of the load of the 110kV substation on the 9th.

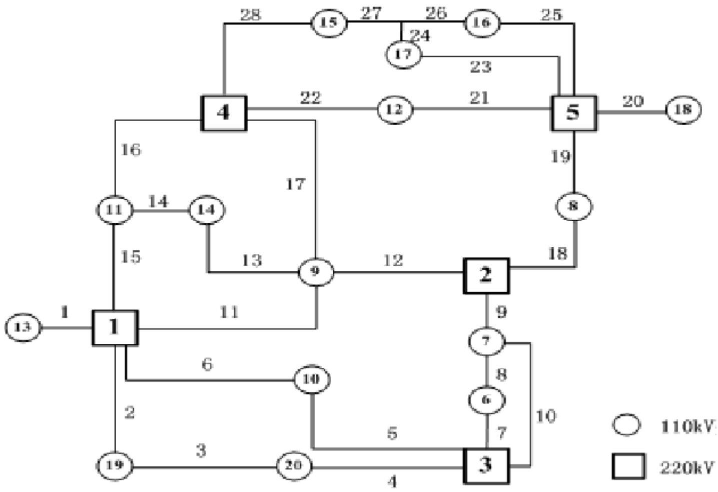

Figure 1. 20-node network wiring diagram

In Figure 1, there are five 220kV substations and 15 110kV substations, and a virtual 110kV station is set up on the T-connection line. Therefore, there are 28 transmission lines in total, corresponding to 28 variables. The initial operation mode of the power grid is shown in Table 1, corresponding to Figure 2. The maximum current carrying capacity of all transmission lines is 600A.

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Table 1. Initial operation mode of the power grid

Serial **number**	**Sn (MVA)**	110kV substation			
1	110	11	13	14	19
		30MVA	30MVA	5MVA	20MVA
2	110	7	8	9	
		20MVA	40MVA	40MVA	
3	100	6	10	20	
		30MVA	45MVA	15MVA	
4	100	12	15		
		50MVA	15MVA		
5	100	16	17	18	
		20MVA	20MVA	20MVA	

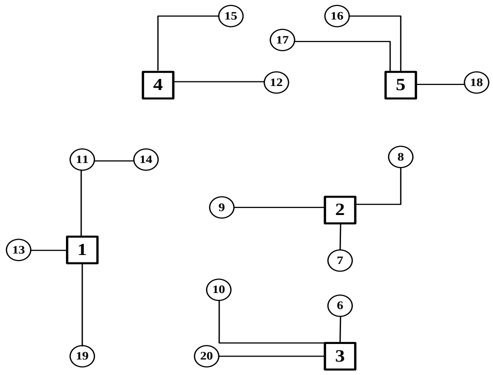

Figure 2. Initial operation mode of the grid

4.1 Power failure maintenance on Lines 14 and 9

Lines 14 and 9 were blacked out for maintenance, and the 110kV substation loads corresponding to No. 14 and No. 7 were transferred from the No. 1 and No. 2 220kV substations respectively. According to the initial operation mode of the grid, the new ones were solved by equations (1) to (4). The operation mode is shown in Figure 3.

In Figure 3, the red line segment is the maintenance line. After the operation mode is optimized, the No. 14 110kV substation is powered by the No. 2 220kV substation through the No. 9 110kV substation, and the No. 7 110kV substation is directly converted to the No. 3 220kV substation. Since the main transformer capacity of the No. 3 220kV substation exceeded the rated value at this time, the load of the No. 20 110kV substation was transferred to the No. 1 220kV substation.From the original operation mode to the optimized operation mode, the state change of the transmission line is 6, that is, the state of the six lines has changed, including the two lines that need power failure maintenance on the 14th and the 9th, which are solved

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as a whole. Optimal solution.

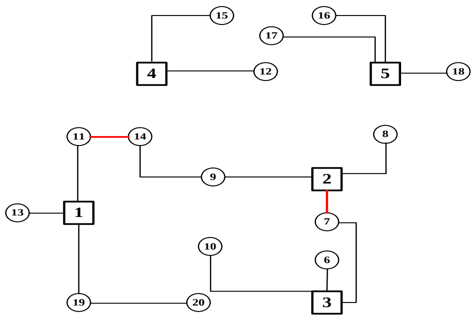

Figure 3. Operation mode during line power failure maintenance

4.2 Main transformer overload of No. 2 220kV substation

Assume that the No. 2 220kV substation itself has a load of 15MVA, so the arrangement in Table 1 will inevitably lead to the main transformer overload of the No. 2 220kV substation, and the grid operation mode needs to be re-arranged. According to the optimization model, the new operation mode is shown in Figure 4.

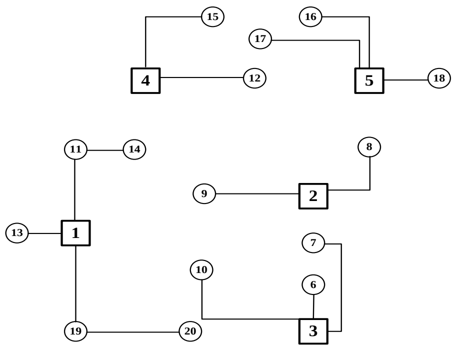

Figure 4. Operation mode of 220kV substation main transformer overload

After the main transformer of No. 2 220kV transformer is overloaded, the load of No. 7 110kV substation will be supplied by the No. 3 220kV substation, while the No. 20 110kV substation will be powered by the No. 1 220kV substation due to the mode adjustment of the No. 3 220kV substation main transformer overload. The optimization result shows that the target function, that is, the state change of the transmission line state is 4, and the global optimum is achieved.

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4.3 No. 9 110kV substation load increase

Assume that the load on the No. 9 110kV substation increases to 80 MVA as the demand for electricity increases. According to the arrangement of Table 1, after the load of the No. 9 110kV substation is increased, the main transformer of No. 2 220kV substation is seriously overloaded. At the same time, if only the substation No. 2 is supplied with power, the current carrying capacity of No. 12 line is too large, which does not meet the thermal stability requirement. Therefore, it is necessary to split the No. 9 110kV substation bus.Assume that there are two main transformers in the No. 9 110kV substation. After the bus splitting operation, the two main transformers each have a load of 40MVA. The operation mode after optimization and reconstruction calculation is shown in Figure 5.

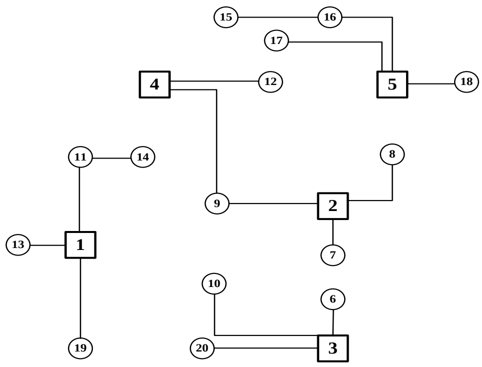

Figure 5. Operation mode when the load increases

It can be seen from the optimization results that the No. 2 and No. 4 220kV substations are simultaneously powered after the split line operation of the No. 9 110kV substation, and the load on the No. 4, No. 2 and No. 3 220kV substations is done in order to meet the requirements of the main transformer capacity. The corresponding adjustment. The objective function has a minimum value of 4 and is solved as a global optimal solution.

5. Conclusion

Based on the actual work content of the regional power grid control center, this paper proposes a preliminary regional power grid reconstruction mathematical model based on 0-1 nonlinear programming with the objective function of "the whole network transmission line state change" as the objective function. The model can optimize the operation mode under different conditions such as daily maintenance, main transformer or line overload of the power grid, and obtain the control scheme of the minimum number of switching operations.Since the constraints such as the tidal section and voltage are not included, the model needs to be further verified, and some

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optimal and suboptimal liberation is released into the PSASP comprehensive program to verify whether the tidal section and voltage meet the requirements, and calculate the corresponding scheme. Line network loss, and finally choose the comprehensive optimal solution. This not only improves the computational efficiency of the optimization algorithm, but also saves computation time, and also makes full use of the advantages of PSASP integrated program in calculating power flow, voltage and network loss, and has a high practical prospect.

References

[1] You Ruhua, Wang Kangyuan, Qian Yuanping. A Practical Method of Network Reconfiguration[J]. Electric Power System and Automation. 2000.12(5). pp:25~28.

[2] Deng Qun. Research on the application of evolutionary stability strategy in distribution network reconstruction and planning [D]. Chongqing University. 2004.

[3] M.A.Kashem, V.Ganapathy, G.B.Jasmon. A novel approach for network reconfiguration based load balancing in distribution networks. Electric machines and Power Systems. 2000, (28) :415~431.

[4] Shirmohammadi D, Hong H W. Reconfiguration of Electric Di stribution Networks for Resi stive Line Loss Reduction[J] .IEEE Trans on PWRD, 1989, 4(2):1492~ 1498.

[5] Civanlar S, Grainger J J, Yin H, Lee S S H. Distribution Feeder Reconfiguration for Loss Reduction[J] . IEEE Trans on PWRD, 1988, 3(3): 1217~ 1223.

[6] Chen Genjun, Li Jizhen, Tang Guoqing. Distribution Network Reconfiguration Algorithm Based on Tabu Search[J]. Proceedings of the CSEE, 2002.22(10). 28~33.

[7] Pedro Faria,Tiago Soares,Zita Vale,et al.Distributed generation and demand response dispatch for a virtual power player energy and reserve provision.Renewable Energy,2014,66:686-695

[8] Abreu LVL,Khodayar ME,Shahidehpour M,et al.Risk-constrained coordination of cascaded hydro units with variable wind power generation. IEEE Transactions on Sustainable Energy, 2012, 3(3):359-68

[9] Kuk-Hyun H,Jong-Hwan K.Genetic quantum algorithm and its application to combinatorial optimization problem.In:Proceedings of IEEE international conference on evolutionary computation.California, USA:IEEE, 2000,1354-60

[10] Yue Shen,Changyun Xu,Haozhong Cheng.Reconstruction sequence algorithm for replacing overhead lines by underground cables based on priority weights method.Power System Technology,2004,28(12):5-9

[11] Yuliang Qian,Hao Zhang,Daogang Peng,et al.Orbit purification of generator unit based on a new generalized particle swarm optimization method.Proc CSEE,2012,32(02):130–7