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Research and Application of Power Communication Business Routing Planning

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Abstract

To achieve rapid and reliable restoration of power communication services in the event of faults, this paper proposes a model for the routing planning of power communication services, which intelligently plans reliable routes under fault conditions, enabling the rapid restoration of critical production operations. The practical application results show a 68% reduction in restoration time and an 11% improvement in route reliability, effectively ensuring the safe and stable operation of the power grid.

Keywords

Power Communication Network; Power Communication Service; Routing Planning.

1. Introduction

The power communication network is used to transmit power grid production control and management information services, playing a crucial role in ensuring the safe and stable operation of the power grid. In recent years, with the continuous innovation and development of technology, the level of intelligence of the power communication network has been increasing, and the number of power communication services it carries has been growing rapidly, greatly increasing the burden and workload of power grid communication [1]. Once the power communication network experiences operational faults, it will lead to unplanned interruptions of power communication services, which could seriously jeopardize the safe and stable operation of the power grid.

In the event of faults in the power communication network, affected power communication services are often rapidly restored through routing detours. When formulating detour routes, it is necessary to ensure the timely recovery of services on one hand, and to ensure that the detour routes comply with service configuration rules, thus preventing concentrated risks and improving the reliability of detour routes. Since the implementation of the “Notice on Issuing the Safety Accident Investigation Procedures of State Grid Corporation of China” by the State Grid Corporation of China, higher requirements have been placed on the security and stability of the power communication network [2]. The traditional manual methods of devising detour routes can no longer meet the assessment requirements in the new situation. Therefore, the intelligent planning of detour routes for power communication services in the event of faults is an urgent problem to be addressed.

2. Power Communication Network Service Configuration Mode

Currently, the power communication network services are mainly based on fiber optic transmission. The common service configuration modes can be categorized into two major types: one is “single service, single channel,” where a single service corresponds to a single channel route, and the other is “single service, dual channel,” where a single service corresponds to two different channel routes, as shown in Figure 1.

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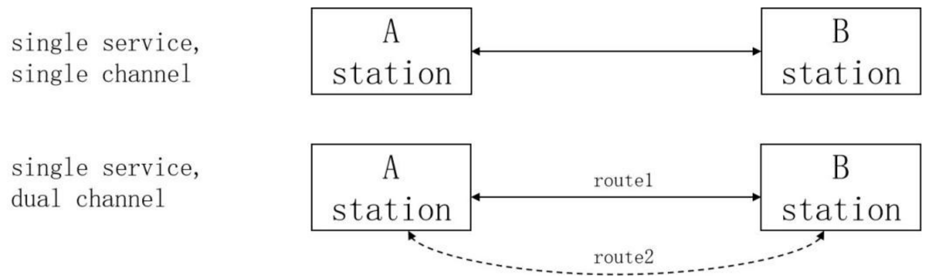

Figure 1. The service configuration modes

To enhance the reliability of power communication services, most power communication services are redundantly configured. For services with low transmission delay requirements, the SNCP protection form is generally used, where both ends of the power user equipment are connected to a power interface, and two different channel routes are configured. Through the principle of dual-end selection and reception, the better-quality signal is selected for transmission from the two signals, and if the quality of the two signals is similar, the default route is selected for signal transmission [4]. For power grid production control services, such as relay protection services, which typically have high transmission delay requirements, equipment redundancy is usually employed to enhance service reliability. For example, redundancy configurations for protection devices and stability control devices. In recent years, to further enhance the reliability of service channels, dual-port configurations such as device A/B ports and 2M switch devices have been introduced, automatically switching to the backup port when the main channel route is unavailable, ensuring that power communication services operate normally without being affected. For relay protection services, the redundancy configuration mode typically adopts the “single service, single channel” configuration to ensure that the relay protection services can function correctly in the event of a fault. The business redundancy configuration mode is shown in Figure 2.

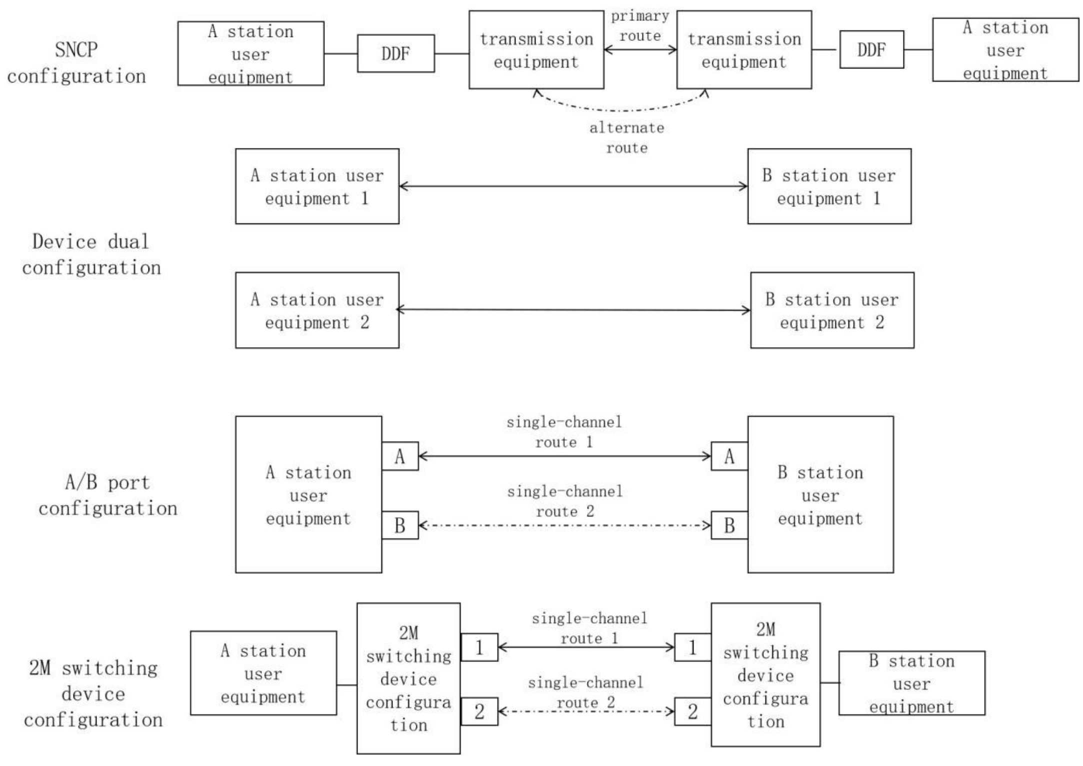

Figure 2. The service configuration mode diagram

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3. Service Routing Planning Principles of Power Communication Network

When abnormal situations occur in the power communication system, it will result in the unplanned interruption of service channels, requiring the use of network management routing detours to quickly restore the affected service channels. When devising detour routes, the following three principles should be followed:

(1) Detour routes should use OPGW optical cables of the same voltage level and be transmitted using SDH equipment, with the transmission equipment having at least two optical transmission directions.

(2) When devising detour routes, consideration should be given to the maintenance work situation, and whether the optical cables or equipment passed through by the detour routes will meet the requirements of the maintenance work, ensuring that the detour routes are reliable and stable.

(3) For relay protection service channels, the three-path requirement should be met to ensure that the protection services can continue to operate normally even if any two of the protection channels fail and cannot be used.

4. Routing Planning Model of Power Communication Business

Based on the business configuration mode of power communication network and the routing planning principles, in the event of a communication network failure, detour routes should be formulated taking into account the impact of maintenance and the configuration of communication optical cables and equipment resources. This is to ensure the availability of detour routes. Furthermore, for relay protection services, available detour channel routes should be selected in accordance with the three-path configuration requirements for protection services, aiming to enhance the reliability of relay protection services. In accordance with these requirements, a power communication business routing planning model is developed, as shown in Figure 3.

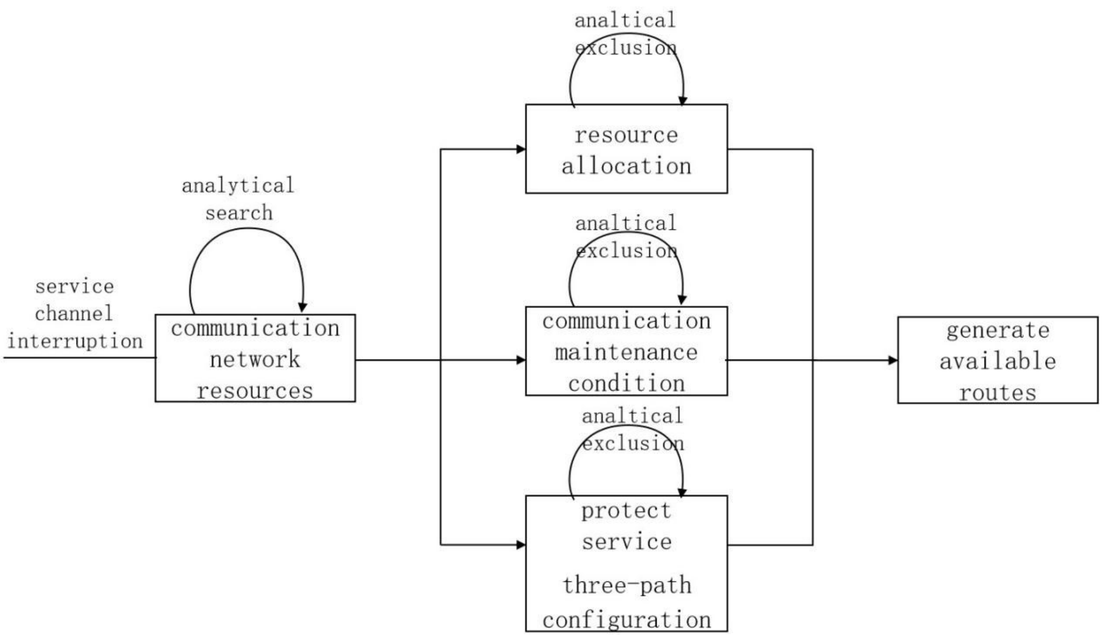

Figure 3. A power communication business routing planning model

According to the power communication business routing planning model, in the event of a power communication network failure causing an interruption in the power communication business channel, a rapid analysis and search of the entire network communication resources will first be conducted to generate all available detour routes bypassing the fault point. Subsequently, unavailable detour routes will be eliminated in consideration of limiting conditions. Firstly, through the analysis of the overall network resource configuration, detour routes that do not transmit through SDH equipment and those with inconsistent optical cable voltage levels will be excluded. Next, in consideration of ongoing or upcoming communication maintenance work at the time of the fault occurrence, detour routes affected by maintenance will be excluded. Finally, if the relay protection business channel is interrupted, three-path configuration analysis will be performed to eliminate detour routes that do not meet the three-path requirement. After the three-step analysis and elimination process, the available detour channel routes can be obtained.

5. Service Routing Planning Algorithm for Electric Power Communication Network

Based on the business channel planning model of power communication, the practical execution mainly involves two major algorithmic steps: first, the analysis and search of the entire network communication resources, and second, route analysis and elimination.

5.1 Analysis and Search of Communication Network Resources

Combining the situation of the power communication network system and the routing planning model, the communication system can be abstracted as an undirected graph model. Using the undirected graph and the adjacency matrix method, analysis of the connectivity between nodes will be conducted to derive the information on available channel routes in the entire network, and to determine the available channel route scenarios. The model of the communication system abstracted as an undirected graph is shown in Figure 4.

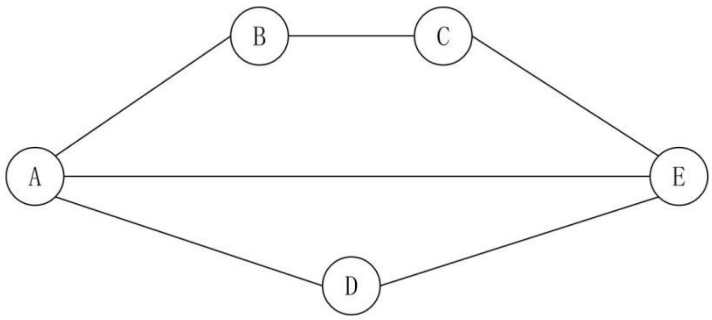

Figure 4. The model of undirected graph

The undirected graph model of Figure 4 can be represented as $G=(V,E)$ where $V=\{v_1,v_2,\cdots,v_n\}$, and a_{ij} denotes a Boolean value indicating whether v_i is adjacent to v_j, i.e., whether there is a direct connection between the nodes. The adjacency matrix for G is denoted as $(a_{ij})_{n\times m}$ and is recorded as $A(G)$.

$$\mathbf{a_{ij}}=\begin{cases}\mathbf{0;\ There\ is\ no\ adjacent\ edge\ from\ point\ i\ to\ point\ j.}\\ \mathbf{1;\ There\ are\ adjacent\ edges\ from\ point\ i\ to\ point\ j.}\end{cases}$$

The adjacency matrix of the undirected graph shown in Figure 4 can be represented as follows:

$$\mathbf{A(G)}=\begin{bmatrix}\mathbf{0} & \mathbf{1} & \mathbf{0} & \mathbf{1} & \mathbf{1}\\ \mathbf{1} & \mathbf{0} & \mathbf{1} & \mathbf{0} & \mathbf{0}\\ \mathbf{0} & \mathbf{1} & \mathbf{0} & \mathbf{0} & \mathbf{1}\\ \mathbf{1} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{1}\\ \mathbf{1} & \mathbf{0} & \mathbf{1} & \mathbf{1} & \mathbf{0}\end{bmatrix}$$

The first row of the adjacency matrix $A_1^{(1)} = (0\ 1\ 0\ 1\ 1)$ indicates that in Figure 4, point A can directly reach points B, C, and E in one step. To determine the nodes that point A can reach in 2 steps, $A_1^{(2)}$ needs to be computed.

$$A_1^{(2)} = A_1^{(1)} A(G) = (0\ 1\ 0\ 1\ 1)\begin{bmatrix} 0 & 1 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 1 & 0 \end{bmatrix} = (1\ 0\ 1\ 1\ 1)$$

This shows that the nodes A can reach in 2 steps are C, D, and E.

Following this calculation process, as there are a total of 5 nodes in the graph, $A_1^{(5)}$ needs to be calculated at least in order to determine whether A can reach each node and how many steps are required to reach each corresponding node.

Based on the undirected graph and the adjacency matrix method, the connectivity between nodes and the number of steps required to reach each node can be quickly calculated, completing the rapid search and analysis of the entire network's communication resources.

5.2 Route Analysis and Elimination

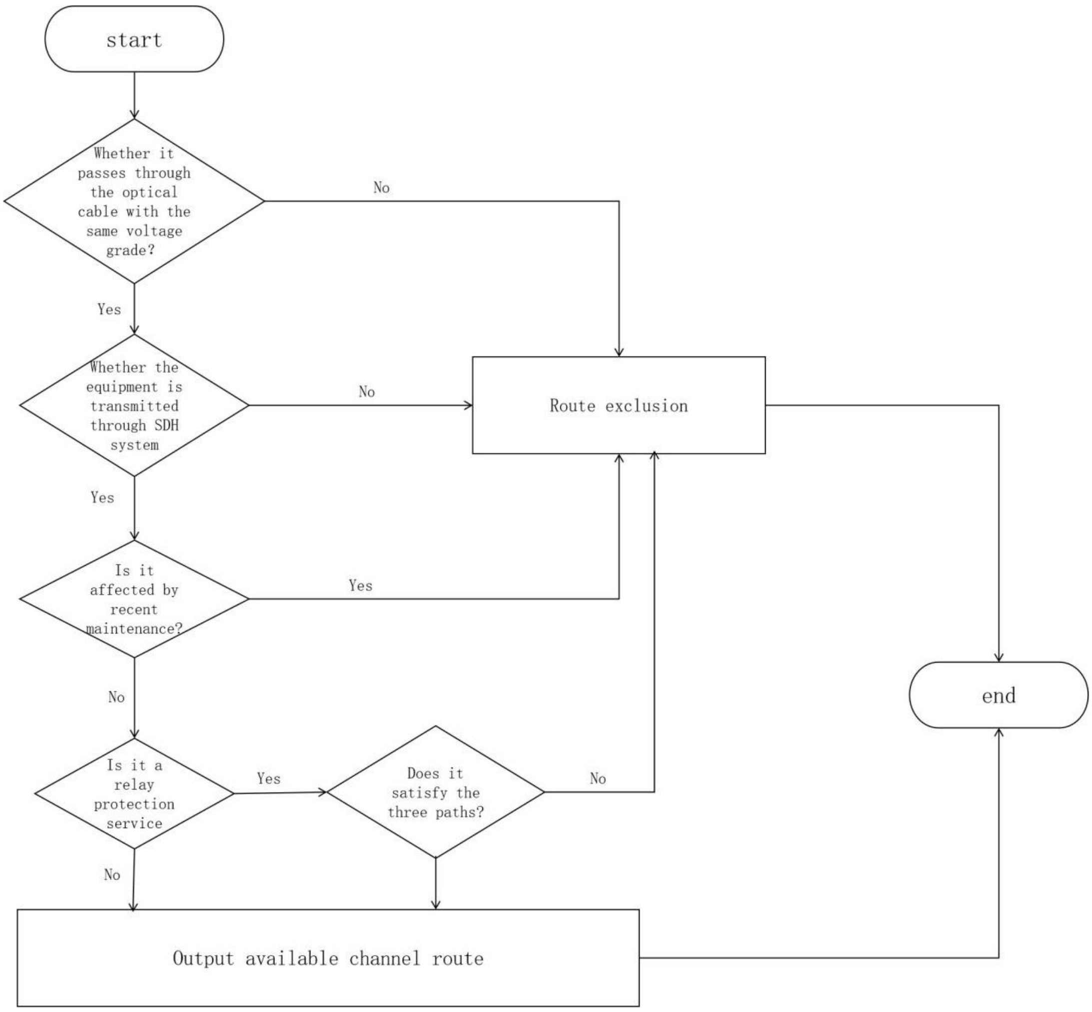

Figure 5. The process diagram of route analysis and elimination

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After the traversal search of the entire network resources, multiple bypass channel routes will be generated. However, not all these routes are equally usable and reliable in practice. The next step involves analyzing and excluding routes that do not meet the criteria in terms of voltage level, equipment passage, maintenance impact, and protection service three-path configuration. The specific analysis process is shown in Figure 5.

During the process of routing analysis and elimination, the first step is to determine whether the channel routes pass through the same voltage level of optical cable. If the route passes through the same voltage level of optical cable, further examination is needed to assess whether it passes through SDH transmission equipment and whether there is routing across different transmission systems. If all the transmission is through SDH transmission systems, further investigation is required in conjunction with recent maintenance work. If the route has not been affected by recent maintenance impact, the next consideration is whether it needs to bypass a relay protection service. If so, the route must meet the three-path configuration before being considered as an available bypass channel route. If not, the route can be directly considered as an available bypass channel route.

6. Model Application and Analysis

To verify the accuracy of the power communication service routing planning model proposed in this paper, 50 communication optical paths were selected. Simulation experiments were conducted to validate the reliability of the model's planned bypass routes. At the same time, the time for establishing the bypass route using the model was compared with the manual method to determine the effectiveness of the routing planning model in reducing the time required to establish the bypass route. This simulation experiment was divided into two comparison test groups. Group A used the traditional manual method to establish the bypass route, while group B directly generated the bypass route through the routing planning model. The experimental data is shown in Table 1.

Table 1. Data of comparative test

Test groups	Total time for establishing the bypass route /Minutes	Total business paths/lines	Correct number/paths	Incorrect number/paths	Accuracy rate
Group A (manual method)	1254	246	201	45	82%
Group B (model)	401	246	228	18	93%

Based on the comparison test data in Table 1, the total duration for establishing the bypass route using the model was 401 minutes, with an accuracy rate of 93%. In contrast, the time taken for manual establishment of the bypass route was 1254 minutes, with an accuracy rate of 82%. The duration for establishing the bypass route using the model was 68% shorter than the manual method, with a simultaneous 11% increase in accuracy. According to the experimental results, it can be concluded that the use of the power communication routing planning model significantly improves the accuracy of bypass routes and reduces the time required to establish them, thus significantly enhancing work efficiency.

At the same time, the experimental results also showed that the accuracy rate of the routing planning model did not reach 100%, with 18 services having inaccurate or unavailable channel route planning. For these 18 services, the reasons for the inaccurate routing planning were analyzed, as detailed in Table 2.

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Table 2. Reasons for incorrect bypass route

Reasons	Inaccurate resource data	Inconsistency in resource data
Number	13	5
Proportion	72.2%	27.8%

The main reasons for the inaccurate establishment of the bypass route were inaccurate resource data, indicating the need for real-time updating and dynamic management of resource data to improve the accuracy of the routing planning model. Another reason was data inconsistency, where business channels passed through the transmission equipment of units A and B simultaneously, but the inconsistency in resource data led to inaccurate analysis of the business channel route, highlighting the need for coordinated data consistency management.

7. Conclusion

With the intelligent development of power communication networks, intelligent communication operation and maintenance, balanced communication risk, and flexible communication scheduling will become the development trend of power communication networks [5]. With this development trend, the number of communication services supported by power communication networks will continue to grow, and the responsibility to support the safe and stable operation of the power grid will continue to increase. Therefore, the automatic planning model of power communication network services will play an increasingly important role in intelligent scheduling, communication guarantee, and communication operation and maintenance in various scenarios.

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