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Design of Communication Maintenance Automation Tools for Differential AC Protection Services

Lei Wang*, Yan Liu, Yizhan Quan

State Grid Henan Information & Telecommunication company, China

*519271097@qq.com

Abstract

With the rapid development of the power grid and communication network, the production control business carried by the communication network, such as differential AC protection, presents characteristics of "wide coverage, large number of businesses, and complex channel modes." Currently, due to the lack of automatic analysis tools, traditional offline manual methods are still employed when performing communication maintenance impact verification and other tasks, which is time-consuming, laborious and inefficient. This paper designs an analysis tool for communication maintenance impact under the existing Telecommunications Management System (TMS) of the State Grid Corporation, establishing a unified routing ledger and bearer relationship for production control businesses such as differential AC protection, and automatically verifies various production control business channels during maintenance using a rule-based resource impact analysis algorithm.

Keywords

Management System; Analysis Algorithm; Relationship.

1. Background

During communication maintenance or fault handling, communication dispatchers manually analyze the impact range of production control business channels such as differential AC protection, formulate emergency support plans, and this process is inefficient and time-consuming, which easily leads to safety incidents or causes expansion of power grid accidents [1]. During the period of the exceptionally heavy rainfall in Zhengzhou on "7.20" in 2021, the communication equipment at the 500kV Songshan and Guandu substations faced the risk of immersion and total shutdown, with Songshan substation carrying over 2700 businesses and Guandu substation carrying over 3200 businesses. The human-operated verification would require 3 hours to complete the analysis of the impact ranges of over 5000 businesses, meeting the safety verification requirements. In response to such problems, the development of an automatic analysis tool for communication maintenance impact reduced the hourly workload to minutes during the heavy rainfall in Zhengzhou on "7.20," achieving online analysis of communication business safety verification.

2. Overall Design and Functions

The overall functional design of the automatic analysis of maintenance impact on business relies on the resource data of State Grid Corporation's Telecommunication Management System (TMS) and implements business routing and maintenance impact analysis functions to achieve unified business routing management and automatic analysis of maintenance impact on business [2].

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2.1 Business Routing Management

Establish six standardized routing forms and build channel association relationships for protection, security control, business routing, optical path routing, fiber optic cable routing, and carrying routing through the nested fields of each standardized form. Based on TMS fiber optic, optical path, and business resource accounts, the logical routing of business and optical path channels collected by the network management system (NMS) (equipment-port-time slot-optical path) and the physical routing of fiber optic cable formed by wiring connections (equipment-port-wiring terminal-fiber optic cable core) are analyzed through standardized channel association relationships to build a mapping structure (equipment-port-time slot-fiber optic cable core) and form fiber optic cable, optical path, and business account data.

2.2 Rule-based Resource Impact on Business Analysis

2.2.1 Business Impact Analysis

Firstly, the physical paths of optical paths and business are collected, and the affected communication physical resources are transformed into affected optical path resources based on the resource association relationship. Then, rules are established based on logical relationships (such as optical switch main/backup, 1+1 main/backup optical path, single optical path; same tower/different tower dual-redundant fiber, aerial/canal/tunnel installation form; SNCP, single channel configuration) to analyze and determine the optical path and affected business. In addition, rules for the discrimination of redundant configuration in line protection, security control, and dispatch data network business are formulated, guiding the analysis of grid operation risks based on communication channel risk analysis. Combined with disaster impact prediction, the analysis automatically calculates the impact of multi-point and multi-line faults on the communication network and power grid, issues early warnings, and guides disaster prevention and reduction work for the communication network.

2.2.2 Analysis of Remaining Channel Operational Status

Based on the analysis of the impact on business, the set of remaining normal protection business channels on the same line route is extracted from the business “one-account” resource information, and the analysis of the operational status of all normal communication business channel routes is carried out based on the optical cable “one-account” resource information to determine whether they exist on the same cable and the same trench.

2.2.3 Measures Analysis

Based on the analysis of the affected status of optical path, protection, and security control business channels, measures are taken according to the protection configuration information. For the optical path channel, corresponding measures are output through 1+1 MSP and optical switch protection relations. For protection and security control channels, through the protection relations of protection device single port, A/B ports and 2M1+1 devices, security control device A/B plane, and 2M 1+1 device protection relations, measure analysis results are output following the standardized reporting rules for maintenance measures issued by the higher authorities.

2.2.4 Issue Maintenance Tickets

The results of the business impact analysis are sent to maintenance tickets and plans, and the maintenance content, impact on business, measures taken, and operational status are automatically filled in, achieving one-click filling of maintenance tickets.

3. Technical Innovation

3.1 Innovative Platform Architecture

Adopting a microservices and microapplications architecture. Based on the communication management system platform, a microservices and microapplications architecture is used, spanning the production control zone and the management information zone. It has the advantages of low

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coupling, high performance, easy maintenance, flexible deployment, open functionality, and rapid iteration [3].

3.2 Enhancing Data Quality

Establishing a "cross-system" unique identity ID code to improve data quality. Standardizing the naming of various business data networks such as protection, security control, and dispatching, and establishing a "cross-system" unique identity ID code for business channel information. This includes implementing real-time incremental collection and collection of business channel names and tag IDs to ensure data consistency between the transmission network management system and the TMS system, thereby improving data resource quality and ensuring the accuracy of business impact analysis [4].

3.3 Achieving Seamless Resource Integration Across Transmission Networks

Build a dynamic association model between physical resource data and logical routing data on the professional network management side. Automatically splice and supplement fragmented communication information between service resources, optical path resources, channel resources, and service channel-related resources, branch calculation for ports with time slot cross, find the branches to address multiple paths, determine the information for this transmission segment. Complete the physical routing splice from the connection point through the analysis of transfer channels to achieve complete routing of service channels [5]. Overcome the difficulties of channel cross-network, 2M port switching, and interruption of channel routing data caused by opto-electrical switching, solve the problems of incomplete data analysis and inability to show the impact range under different networking methods.

4. Application Scenarios and Effects

"One-click report" for communication maintenance impact analysis on business. Through the analysis of the impact of single-point maintenance of optical cables and equipment or single-point failures in the communication network on business, assisting maintenance personnel in reporting and approval of communication maintenance affecting business, automatically verifying 376 Level 3 network maintenance tickets, reducing the verification time to minutes, and achieving 100% accuracy in the verification of protection and security control business.

The deployment and application of the "business impact analysis tools for communication maintenance". It has achieved a transformation in the security of communication network operations from "offline manual" to "online intelligent" verification, reducing typical work scenario times to minutes and achieving a hundred-fold efficiency improvement. The communication network dispatch operation has shifted from "equipment-oriented" to "business-oriented" control, making fault handling and maintenance planning more effective in ensuring business support. The approach to communication network security risks has transitioned from "simple and extensive" to "multi-dimensional and precise" control, with more targeted measures in hazard management, operations, and disaster response, providing all-round business safety protection.

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