Research on the Intelligent Transformation of Electrical Handover Tests

Lei Yang, Song Lin, Jing Yan, Fangyi Xie, Fuxiang Guo
Beijing Northstar Technology Development Co., Ltd., Beijing, China

Abstract: With the in-depth advancement of the digital transformation of power grids, the traditional handover test mode relying on manual recording and paper documentation has increasingly revealed bottlenecks in operational efficiency and data accuracy. Its intelligent transformation has become an inevitable requirement for industry development. This paper focuses on the core path of this transformation: through intelligent data acquisition devices, it breaks down the data interface barriers between different test instruments, and constructs a solution integrating automatic test data acquisition, real-time and reliable transmission, as well as data judgment and standardized report automatic generation. Practical applications show that this path has effectively achieved paperless test processes, source automation of data acquisition, and preliminary intelligence of result determination. It not only significantly improves on-site work efficiency and data quality, but also lays a solid data foundation for building complete digital equipment archives and realizing full-lifecycle refined management.

Keywords: Handover Tests; Intelligentization; Automatic Data Acquisition; Intelligent Judgment; Digital Transformation

1. The Inevitable Trend from Traditional to Intelligent

Nowadays, electrical equipment Handover Tests still generally adopt the traditional operation and management mode centered on "manual operation, paper recording, and post-processing". Faced with the continuous expansion of power grid scale, the increasing complexity of equipment, and the deepening requirements for digital transformation and refined management, its inherent and systemic drawbacks are gradually magnified, becomes a hinder which is restricting efficiency and quality [1]. Promoting the transformation of electrical Handover Tests from a traditional mode relying on personal experience to an intelligent mode driven by data has become an urgent and inevitable engineering practice requirement. Specifically, the traditional mode can be summarized into the following three progressive core problems, and intelligent transformation provides direct and efficient solutions for each of them.

1.1 Main Problems Faced by Traditional Handover Tests

1.1.1 Data quality relies on personnel capacity, data sources are difficult to trace

In the traditional mode, the acquisition of on-site test data is highly dependent on manual intervention, and data quality is significantly affected by humanly factors, which makes the source of test data difficult to be traced, as is shown in Figure 1. Specifically, test personnels need to observe the curves or values displayed on the instrument screen in complex on-site environments and manually record them in paper forms, with the entire process usually lacking real-time review. This not only places high requirements on personnel's sense of responsibility, concentration, and proficiency in instrument reading, but also further increases the workload and error probability when testing items involve a large amount of recorded data (such as excitation characteristic curve test for potential transformer).

As the data is deeply related to the operation of the test personnel at its generation stage, its authenticity cannot be effectively verified in subsequent stages, so that the corresponding relationship between original data and final records is also unclear. This "black box" data generation and recording method lays hidden dangers for subsequent data processing, equipment status evaluation, and advanced data analysis. Any intelligent analysis and decision-makings based on data premised on the authenticity and accuracy of source data, but the traditional mode has insurmountable defects in this basic link.

Figure 1. Manually Recorded Data at the Handover Test Site

1.1.2 Tedious data post-processing and laborious cross-departmental coordination

In the traditional mode, the tedious data processing work only truly starts after the tests are completed, and due to the involvement of cross-departmental collaboration, the overall efficiency is difficult to guarantee. Specifically, after the on-site tests, technical personnel first need to manually enter the massive data from paper records into computers for sorting, calculation, and summary, which is essentially a repetitive labor of on-site data recording. Subsequently, they also need to manually judge every test data in accordance with relevant standards. It is worth noting that in the subsequent report compilation stage, since the report compilation department and the test execution department usually belong to different sections, the two need to conduct repeated communication and confirmation on data accuracy, format standardization, conclusion expression, etc. This cross-departmental coordination process is often time-consuming, and prone to information transmission deviations. Finally, the test personnels also need to organize and adjust the report content multiple times to form an official version that meets all the submission requirements.

1.1.3 Lack of management in the operation process and difficulty in real-time supervision

On a more macro management perspective, the traditional mode is characterized by loose process management. Test tasks are often issued in unformal ways, and with the final test report as the only basis of completion, the progress of handover tests are often controlled by the test personnels themselves. Managers find it difficult to effectively supervise and coordinate multiple on-site operations. Management in this method fails to identify and resolve operational risks in a timely manner, also makes it difficult to trace the progress of the handover tests.

1.2 Intelligent Handover Test Solution

1.2.1 Automatic acquisition of source data

To solve the quality and efficiency problems caused by manual data recording, human factors must be eliminated from the chain of data generation and passage. The very basic for intelligent transformation lies in implementing automatic acquisition of source test data. Specifically, by deploying intelligent data acquisition devices (shown in Figure 2) on various test instruments, direct communication connections are established with equipment such as dielectric loss testers and loop resistance testers through standard physical interfaces (such as RS-232 and USB) [2,3]. The device can automatically acquire and parse the original message output by the instruments without manual intervention. Based on this technical solution, data is directly acquired in a digital and structured form from the moment of generation, completely eliminated the errors may be introduced by manual transcription, and laying a uniquely credible and fully traceable data foundation for intelligent processing and analysis.

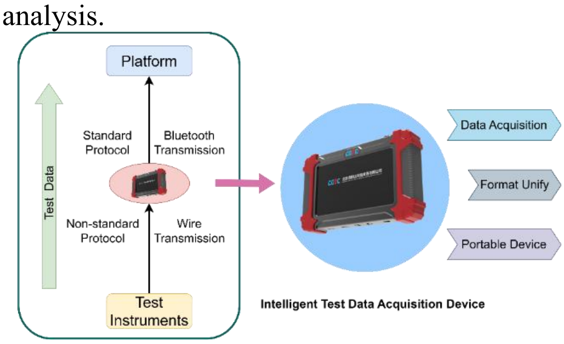

Figure 2. Intelligent Test Data Acquisition Device

1.2.2 Automatic data judgment and report generation

Based on the real-time and structured data flow formed by automatic acquisition, the intelligent system can systematically reconstruct and post-process the test data. The solution mainly includes the following two stages:

(1) The system has a built-in standard base including national standards, enterprise standards and calculation formulas for the handover tests, and which are flexibly configurable [4]. After the test data is acquired, the system completes data calculation (such as difference calculation or temperature conversion), comparison between measured values and standard thresholds in a very short time, then outputs judgment conclusions, and triggers early warnings for abnormal data, carried out completely under objectivity and standardization.

(2) The system stores preset standardized report templates for handover tests, which can automatically associate equipment parameters, factory test data, on-site test data, and judgment conclusions. After the handover test is completed, it quickly generates formal test reports with a unified format and complete content [5,6].

1.2.3 Online test task management system

To solve the problems of massive test tasks and the lack of process tracking in the traditional mode, it is necessary to build an online information-based system covering task planning, execution management, and result view. Which will lead the transformation of test management from result acceptance to process controllability [7].

(1) Test tasks management. Managers can formulate test plans on the system according to project requirements, which clarify task content, test equipment, execution personnels, and time nodes, fully replacing the unformal tasks assignment method to ensure clear instructions and assigned responsibilities.

(2) Real-time task progress monitoring. After the test personnels received assigned tasks, on-site data will feedback in real-time and display to the test managers which includes task status, personnel location, completion status, and abnormal warnings of all tasks through visual dashboards, realizing the full-process supervision of the handover test process.

(3) Online reports approval process. Test reports will automatically enter online reports approval process, the manager in charge can make annotations, modifications and signatures online, which greatly shortens the report review period and forms complete and standardized digital test documents.

1.3 Chapter Summary

In this chapter, we systematically discussed the necessity and implementation path of the transformation of handover tests from the traditional mode to the intelligent mode. Aiming at the three core problems of the traditional operation—data quality affected by human factors, tedious post-processing, and massive test tasks management—corresponding solutions are proposed: consolidating the data foundation through automatic source acquisition, improving processing efficiency through intelligent judgment and auto report generation, and realizing process management through online system. With the three organically connected, jointly constructing an intelligent new paradigm driven by data, optimized by processes, and coordinated by management, proving a solid foundation for improving test quality and efficiency and management quality.

2. Architecture and Functional Design of the Intelligent Handover Tests System

This chapter will describe the system technical architecture of supporting the entire intelligent transformation. With data flow as the main line and solving the issues mentioned above as the goal, this architecture constructs an intelligent handover test system with three collaborative layers: the on-site operation layer, the computing service layer, and the application interaction layer [8,9], shown in Figure 3.

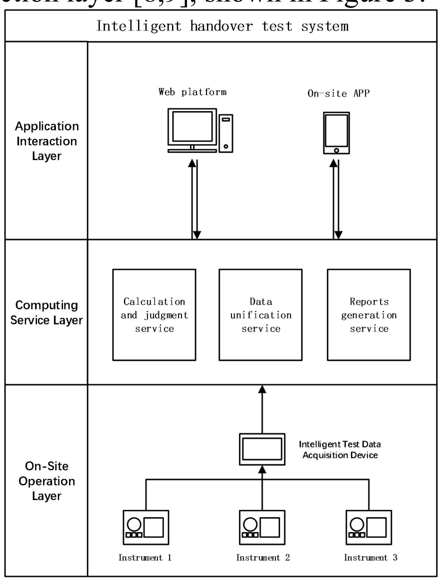

Figure 3. Architecture of the Intelligent Handover Test System

2.1 System Architecture Design

The system adopts a "cloud-edge-terminal" collaborative configuration architecture, which fully considers the convenience of on-site operations, the reliability of data flow, and the practicality of platform functions.

2.1.1 On-site operation layer

The on-site operation layer is the foundation and data source of the intelligent system. Its core lies in establishing automatic acquisition of handover test instrument data by applying intelligent data acquisition devices. These devices are connected to the data interfaces of the instruments, and without interfering the original functions of the test instrument, they extend external communication and active data reporting capabilities for the instrument. During the handover tests, the devices automatically monitor and receive the original message output by the instruments, converts it into a unified format recognizable by the system, and then uploads the standardized and structured data to the computing service layer in real time through the built-in wireless network module.

Essentially, this transformation completes the shift from the traditional analog mode of "eyes and pens" to the digital mode of "automatic acquisition and real-time upload ". It not only fundamentally eliminates fault that may cause by manual recording, but also ensures the objectivity, r timeliness, and consistency of data, thereby providing a uniquely credible original data foundation for the entire intelligent system.

2.1.2 Computing service layer

Computing service layer is the calculating core of the system, deployed in the cloud servers, mainly provides four computing and processing capabilities for the system:

(1) Data unifying service: Responsible for converging, standardizing, and persistently storing multi-source and heterogeneous test data from the on-site operation layer, which constructing a data resource system supporting efficient query and analysis;

(2) Formulas calculation and judgment service: Based on the built-in standard base, automatically analyze, logically judge, and detect abnormalities in real-time and historical test data, output standardized conclusions;

(3) Auto test reports generation service: Automatically invoke corresponding templates and typesetting engines according to structured data and judgment results to generate test reports with standardized format and complete content, for subsequent online reports approval process;

(4) Process scheduling and resource coordination service: Uniformly model and manage test tasks, personnels, equipment and other resources, driving the automatic flow of task execution, status synchronization, and business collaboration.

The computing service layer encapsulates core computing capabilities in a service-oriented manner, providing stable and scalable data processing and business support for application interaction layer.

2.1.3 Application interaction layer

The application interaction layer performs the nexus connecting users and the system, providing differentiated dedicated tools according to various roles. This layer mainly includes two core terminals, to meet the user needs in different scenarios:

(1) On-site data acquisition APP: Designed specifically for on-site test personnel, emphasizing the intuitiveness, guidance, and real-time performance of operations. It is mainly used for task reception and data acquisition during the handover test. In addition, the APP also supports auxiliary functions such as offline storage and photo upload of on-site conditions to adapt to complex environments.

(2) Web integrated management platform: For managers, technical experts, and other reviewers, the platform undertakes online distribution of test tasks, and real-time handover tests progress tracing Managers can grasp the work status, resource distribution, and abnormal situations of each test personnel at any time. It provides multi-dimensional data statistical dashboards, penetrating query and comparative analysis functions of historical data, reaching digitalization, transparency, and traceability of the management process.

2.2 Functional Design

Based on the three-layer system architecture described above, the intelligent handover tests system mainly established the following four core functions, solving the main issues in the traditional mode systematically:

2.2.1 Automatic acquisition of source test data

By deploying intelligent data acquisition devices on test instruments, automatic acquisition of test data can be realized. It completely replaces the original method relying on manual observation and recording, fundamentally eliminating human errors such as misreading and miscounting from the source, ensuring the originality, objectivity, and real-time performance of data, and laying a uniquely credible data foundation for all subsequent processing links.

2.2.2 Automatic judgment of test results and automatic generation of reports

The system platform has a built-in standard rule library and calculation model, which can perform millisecond-level automatic analysis, calculation, and logical judgment on the real-time uploaded test data, and output test conclusions immediately [10]. At the same time, it automatically integrates relevant data, conclusions, and data charts according to preset templates, and generates test reports with standardized format and complete content with one click, freeing technical personnel from tedious and inefficient data sorting and document compilation work.

2.2.3 Full-process online closed-loop management of test tasks

Construct a digital workflow from online task creation, task distribution, on-site execution, progress monitoring to online report review and electronic archiving. Through visual dashboards, managers can transparently grasp the overall progress and resource status, realize precise scheduling and efficient collaboration across departments and levels, and promote the fundamental transformation of the management mode from focusing on final "result acceptance" to refined control and real-time support of the "entire process" [11].

3. Expected Application Effect Analysis

Based on the overall system architecture and core functions described above, this chapter will elaborate on the main expected effects of the intelligent handover test system after investment from four dimensions: on-site operation efficiency, data quality control, management collaboration level, and data asset value. It is expected that the system will promote a systematic improvement of test work, and its value will not only be reflected in immediate work improvements, but also lay the foundation for long-term management optimization.

3.1 Significant Improvement in On-Site Operation Efficiency and Release of Core Productivity

The application of the system will fundamentally change the time allocation of traditional operations. Through automatic on-site data acquisition, the on-site data recording time will be close to zero, allowing technical personnel to focus all their energy on test operations and process safety monitoring. In the subsequent data processing link, the functions of intelligent judgment and automatic report generation can transform the original serial process of "data sorting - calculation and comparison - report compilation - manual review" that takes hours to complete into a parallel and automatic digital process, realizing the generation of test reports within a few minutes after the end of the operation, and effectively shortening the test cycle overall.

3.2 Source Guarantee of Data Quality and Laying a Credible Data Foundation

The system will fundamentally solve the problems of data accuracy and consistency. Directly acquiring original instrument data through intelligent acquisition devices can completely eliminate data source errors caused by manual misreading, miscounting, unit confusion, etc. At the same time, automatic judgment based on a unified and configurable digital rule library ensures the complete consistency of judgment standards and calculation rules, eliminates conclusion deviations caused by differences in human understanding, and transforms data quality from relying on individual consciousness to being guaranteed by system rules and processes.

3.3 Transparent and Controllable Management Collaboration and Improvement of Refined Level

The online closed-loop management system will bring significant changes to the management level. Managers can real-time grasp the progress status, resource distribution, qualification rate, and abnormal warning information of all test tasks through visual dashboards, realizing centralized and transparent scheduling of scattered operations. Online task flow, electronic review and archiving of reports will greatly reduce the communication cost and waiting time across departments and levels, and improve collaboration efficiency. This shifts the management mode from focusing on final "result acceptance" to the refined control and real-time support of the "entire process".

In summary, the application effects of the intelligent handover test system are multi-level and systematic. It not only directly optimizes the operation process, improves data quality and management efficiency, but more importantly, by building high-quality data assets and digital processes, it provides a solid practical foundation and sustainable evolution possibilities for the refined management of electrical equipment and the digital transformation of enterprises.

4. Conclusions and Prospects

Aiming at the three core problems of the traditional handover test mode—difficulty in guaranteeing data quality, low processing efficiency, and extensive process management—this paper proposes and practices an intelligent solution based on automatic on-site data acquisition. By deploying intelligent acquisition devices, building cloud platforms and mobile applications, it realizes the systematic reconstruction of data flow, business flow, and management flow.

4.1 Research Conclusions

(1) Fundamental transformation of data acquisition methods: Through direct connection of intelligent data acquisition devices to test instruments, the transformation from "manual recording" to "automatic acquisition" is realized, ensuring the objectivity and traceability of data from the source, and laying a reliable data foundation for the entire intelligent system.

(2) Process reengineering of business processing modes: Converting standard procedures and expert experience into digital calculating, establishing automatic judgment of test results and one-click report generation, which not only improves work efficiency, but also ensures work quality through standardized processing.

(3) Online transformation of management modes: By building a full-process online management system, transparent management from task issuance to report archiving is realized, making on-site operations monitorable, traceable, and collaborative, and improving overall management efficiency.

4.2 Future Prospects

Based on the data foundation and process framework constructed by this practice, subsequent applications can be deepened in two aspects:

(1) Deepening data value mining: By accumulating the structured test data, further in-depth applications such as equipment status trend analysis and family defect statistics can be carried out to provide more effective data support for equipment operation and maintenance decisions.

(2) Expanding the scope of system applications: Promote the connection of system with related platforms such as equipment management and condition-based maintenance, integrate it into the broader digital management system of enterprises, realize data sharing and business collaboration, and further improve overall operational efficiency.

The intelligent transformation path proposed in this paper is oriented to solving practical problems. Through a pragmatic technical solution, it effectively improves the quality and efficiency of handover test work, and provides a referenceable practical case for the digital transformation of similar scenarios in the power industry.

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