Research on the Review Method of Technical Architecture for Digital Power Grid Projects

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Abstract. In the current digital era, digital architecture management is of vital importance for enterprises to achieve efficient operation and innovation. It is a key link in the process of enterprise digital transformation. Its effective implementation can ensure that the digital projects of the enterprise are closely aligned with the overall strategic goals, improve resource utilization efficiency, and reduce operational costs. Currently, the digital architecture control work of enterprises mainly focuses on the three key nodes of feasibility study, design, and launch. It is carried out manually online using architecture control tools. Since 2023, the digital architecture control tools have embarked on the construction path. After the first stage of development, the project feasibility management, preliminary design management, launch management, architecture asset management, architecture control process management, technical policy management, and basic data version management of the first-level modules have been successfully established. This achievement strongly supports digital architecture management business and effectively solves practical business problems such as low efficiency of the architecture control process, inconsistent basic data templates, and the lack of unified management of self-built project architecture assets, laying a solid foundation for the digital transformation of enterprises.

Keywords: Architecture control tool; Strategic target; Enterprise digital transformation

1 Introduction

At present, the three key nodes of digitalization construction-feasibility study, design, and launch - all have their respective architecture control work carried out manually online within the architecture control tool. Each year, a large amount of human, material, and financial resources are required for resource guarantee. Many digitalization projects that have been submitted often encounter problems such as system design not following the company's overall architecture design and technical route implementation, increased subsequent operation and maintenance costs, insufficient correspondence between system function construction and business requirements, insignificant project investment effectiveness, difficulty in eliminating the problem of repeated data

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entry in the system, lack of prominent practical effects at the grassroots level, deviation between the actual construction content of the system and the preliminary design, and risks in project compliance. The architecture control tool lacks relevant business auxiliary statistical analysis functions and intelligent identification and judgment functions, resulting in insignificant effectiveness brought by the tool and a high workload for front-line personnel.

To fundamentally solve the existing problems and further strengthen digital architecture control work, improve the quality and efficiency of digital project construction, save human resources costs, it is necessary to optimize and enhance the existing digital architecture control tool based on the company's current tool, improve the statistical analysis functions according to business needs, apply artificial intelligence technology to add intelligent review functions, and support digital architecture control work[1–2].

2 Research Status

The construction of the digital architecture control tool began in 2023 and went through the first phase of development. Overall, the construction of the first-level modules for project feasibility management, preliminary design management, online management, architecture asset management, architecture control process management, technical policy management, and basic data version management has been completed. This mainly realizes the support for digital architecture management business and solves practical business problems such as low efficiency of the architecture control process, inconsistent basic data templates, and the lack of unified management of self-built project architecture assets[3–4].

3 Research Contents

3.1 Research on the Application of Intelligent Recognition and Comparison Tools for Project Feasibility Study Reports

This tool, relying on intelligent recognition technology, can achieve multi-dimensional processing of project feasibility study reports. In terms of framework compliance verification, it can automatically identify the titles of each chapter in the report, generate a content framework and compare it with the standard feasibility study template. If there are differences such as missing chapters or inconsistent title formats, it will immediately prompt "template application incorrect", blocking the submission of the pre-review application and ensuring the structural standardization of the report from the source. For the current situation analysis section, the tool uses semantic parsing to extract key information about the architecture, including the progress of system construction, names of integrated systems, interface protocols (such as API, middleware), types of transmitted data (such as business forms, real-time monitoring data), deployment locations (such as local data centers, cloud), and deployment modes (such as physical machine deployment, containerized deployment), and automatically generates a structured current situation analysis list. At the business architecture level, the tool can accurately extract business domains (such as power marketing, power grid dispatching), primary/secondary business functions, and core processes, and simultaneously compare them at the field level with the State Grid's business architecture blueprint. It automatically highlights in red any issues such as mismatched function names or missing process nodes. Taking the feasibility study project of the "Intelligent Distribution Operation and Maintenance System" of a certain city's State Grid company as an example, the tool quickly identified that the report was missing the "Investment Estimation" chapter, triggering a template error warning; it extracted from the current situation analysis that the system needs to be integrated with the "Electricity Information Collection System" through the MQTT protocol to transmit distribution equipment status data and be deployed in the provincial company's private cloud; at the same time, it discovered that the "Fault Repair" secondary function in the business architecture was inconsistent with the "Emergency Maintenance" description in the blueprint, promptly reminding of the need for rectification, thereby reducing the report review cycle from 7 days to 3 days. The implementation of the tool faces three major challenges: first, the recognition accuracy of unstructured text (such as handwritten annotations, text embedded in charts) is insufficient, which may lead to information omissions; second, the feasibility study standard template is dynamically adjusted according to project types (such as new construction, renovation), and the lag in updating the tool's template library may cause misjudgments; third, when the State Grid's business architecture blueprint is updated, the tool's comparison rules need to be reconstructed simultaneously, resulting in high maintenance costs. During the development process, the tool adopted the BERT pre-training model to optimize text recognition and combined named entity recognition (NER) technology to precisely locate architecture information; it achieved flexible template adaptation by building a dynamic template library and version control mechanism; and innovatively introduced a "blueprint mapping engine" to convert blueprint content into computable semantic rules for real-time comparison. This method not only improves the efficiency of feasibility study review but also promotes the transformation of document processing in the energy industry from manual verification to intelligent compliance, providing technical references for similar fields.

3.2 Research on Intelligent Recognition and Verification Tools for the Architecture Design Section of the Feasibility Study Report

This tool can perform multi-dimensional intelligent processing on the architecture design section of the feasibility study report. At the application architecture level, it can identify and extract the application domain, name, and various levels of functions. It distinguishes the types of additions, improvements, or deletions through colors, generates an information list and compares it with the system development list. Inconsistent content is automatically identified and prompted. In the data architecture aspect, it extracts information such as application names and data contents to form a flow list. Based on the enterprise middle platform rules, it determines the correctness of data applications and alerts for suspicious content in real time. At the technical architecture level, it extracts information such as the development platforms used in the five-layer architecture and generates a list. It compares it with the technical route selection table to ensure consistency and can also determine the enterprise middle platform and cloud platform application rules according to the company's requirements, and automatically prompts incorrect content. Taking the feasibility study project of the "Smart Grid Dispatching System" of a power company as an example, when the tool is applied, it identifies the "dispatching monitoring" application domain and the newly added "load forecasting" secondary function under it. This does not match the name in the development list, and an immediate prompt is given. At the data architecture level, it discovers an incorrect annotation for "grid operation data" flow direction, which does not conform to the middle platform data specifications, triggering an alert. At the technical architecture level, it detects that the service layer does not use the company's designated middle platform service and that the hardware equipment is inconsistent with the selection table, promptly identifying the problem and helping the project complete the architecture rectification within one week, with an efficiency increase of 60%. The implementation of the tool faces challenges: Firstly, the description of the architecture design section is not standardized, which may lead to information extraction deviations; Secondly, the enterprise middle platform rules change rapidly, and the tool rules are lagging behind in synchronization, which may lead to misjudgment; Thirdly, the technical architecture is complex in layers, and it is difficult to accurately identify the belonging of some components. During development, the tool optimizes the extraction of architecture information using a deep learning-based text classification model, combines image recognition technology to distinguish color markings; By building a dynamic rule library, it realizes real-time updates of middle platform rules; It innovatively introduces a hierarchical semantic mapping algorithm to precisely match the attribution of technical architecture components. This method improves the accuracy and efficiency of feasibility study architecture review and provides a technical paradigm for intelligent processing of energy industry documents, promoting the standardization of architecture design[5–6].

3.3 Project Outline Design Report: Research on Intelligent Recognition and Verification Tools

This tool can perform multi-dimensional intelligent processing on the project outline design report. It can identify the chapter titles and generate a content framework. When comparing it with the standard template, if there are differences, it will prompt errors and block the pre-review submission. It can extract the information from the overall technical route selection table to form a list, and compare it with the approved feasibility study report and analyze the problems according to the company's requirements. It can identify the comparison table of business, application, data, and technical architecture compliance and the chapter information of the business capability view, and compare them with the feasibility study report, the relevant blueprints of State Grid, or the standards. In cases of non-compliance or incorrect content, it will automatically identify and prompt. Taking the "Intelligent Electricity Consumption Management System" outline design project of a certain power company as an example, when the tool was applied, it was found that the report was missing the "System Test Plan" chapter, and the template was identified as incorrect; in the technical route selection table, "Database Selection: MySQL" was extracted, which was inconsistent with the "PostgreSQL" in the feasibility study report, and it was automatically highlighted in red; at the business architecture level, it was identified that the secondary function "Electricity Payment" was inconsistent with the State Grid blueprint, and an early warning was promptly issued; in the business capability view, it was found that the business process diagram lacked the "Exceptional Payment Handling" node, and it was prompted to be improved, reducing the review cycle from 10 days to 4 days. The implementation of the tool faces challenges: Firstly, the table formats in the report are not unified, which can easily lead to information extraction deviations; Secondly, the relevant blueprints and standards of State Grid are updated rapidly, and the tool's rules for synchronization lag behind, which can lead to misjudgments; Thirdly, the drawing styles of business process diagrams are diverse, and the accuracy of node identification is affected. During development, the tool uses a text recognition model based on BERT to optimize the extraction of chapter titles and table information, and combines graph neural networks to improve the accuracy of node recognition in flowcharts; a dynamic rule library is constructed to achieve rapid adaptation to the updated standards and blueprints. This method improves the efficiency and accuracy of the review of the outline design report, provides technical references for intelligent processing of power industry documents, and promotes the standardization process of project design.

3.4 Research on Multi-View Intelligent Recognition and Verification Tools for the Preliminary Design Report

This tool can perform intelligent processing for the four core sections of the preliminary design report. At the system function view level, it extracts roles, function views and lists to form an information list, compares it with the approved feasibility study application architecture design view to ensure consistency, and simultaneously verifies the matching degree, completeness and business activity correlation of the function views and the list; in the system data view, it extracts information such as data models and classifications, compares it with the feasibility study data architecture design list to ensure logical consistency, and determines the correctness of data storage distribution according to the company's requirements; in the system integration view, it extracts integration scenarios and compares them with the feasibility study system integration design list, and simultaneously verifies the compliance of each element of the integration design; on the system physical view, it extracts deployment topologies and compares them with the feasibility study deployment architecture design list, and based on the requirements of State Grid, determines the correctness of the software environment design; for abnormal content, it automatically identifies and prompts.

Taking a certain prefecture-level State Grid "Distribution Network Automation System" preliminary design project as an example, when the tool was applied, it was found that the "fault location" function in the function view was not reflected in the list, and did not match the "fault diagnosis" function in the feasibility study application architecture view. An immediate prompt was given; in the data view, there were field deficiencies in the logical data model compared with the feasibility study data architecture, triggering an alert; in the integration view, the implementation technology description for "integration with the power consumption information system" was incorrect, and was promptly highlighted in red; on the physical view, the operating system version in the software environment did not meet the requirements of State Grid, and was automatically reminded for rectification, increasing the report review efficiency by 50%.

The challenges faced in the implementation of the tool are as follows: Firstly, the function descriptions in the function view are in colloquial language, which may lead to extraction deviations; Secondly, the accuracy of text recognition within the data model charts is insufficient; Thirdly, when the integration scenarios are complex, the difficulty of element association determination is high.

During development, the tool optimizes the extraction of structured information by using CRF-based named entity recognition technology, combines OCR and image semantic analysis to improve the accuracy of chart text recognition; innovatively introduces the "multi-view correlation verification algorithm" to achieve cross-chapter logical consistency determination. This method promotes the transformation of preliminary design review from manual sampling to full-dimensional intelligent verification, providing technical support for the quality control of project design in the power industry.

3.5 Research on Intelligent Verification Tools for the Online Architecture Review Stage

During the online architecture review stage, this tool can optimize the material submission process and content verification.. It supports online submission of review materials such as preliminary design, functional video recordings, and resource video recordings, simplifying the offline process; at the same time, it enables multi-dimensional intelligent comparison: identifying the functional video recording-generated functional list and comparing it with the preliminary design report functional list, and analyzing problems according to company requirements; identifying the database table files to form a table list, and comparing it with the data entity list extracted from the preliminary design data architecture compliance table; extracting the integration list of the preliminary design integration chapters and comparing it with the integration supporting content; identifying the cloud-based components and virtual machine information in the deployment resource video recording, and comparing it with the resource list of the preliminary design physical deployment view, and also extracting the software and version information in the video recording, and comparing it with the software information list in the preliminary design technology route selection table; abnormal content is automatically identified and prompted.

Taking the online architecture review of the "Smart Customer Service System" of a provincial power grid company as an example, when the tool was applied, after receiving 6 types of review materials submitted by the project online, it quickly completed multiple rounds of verification; discovering that the "Work Order Assignment" function in the functional video recording was not reflected in the preliminary design functional list, an immediate prompt was given; in the database table list, "User Feedback Table" did not match the "Customer Complaint Table" in the preliminary design data entity list, it was automatically highlighted in red; in the integration list, "Integration with Billing System" did not provide corresponding supporting materials, triggering an alert; the K8S version extracted from the resource video recording was 1.23, which did not match the 1.24 version in the preliminary design physical deployment view, and the Java version in the video recording was inconsistent with the technical route selection table, and timely reminders for rectification were given. With the help of the tool, the project review cycle was shortened from 15 days to 7 days, and the problem identification rate increased by 80%.

The implementation of the tool faces three challenges; first, the functional video recordings have blurry images and rapid operations, resulting in deviation in function node identification; second, the database table files have diverse formats (such as SQL scripts, Excel tables), and the extraction of some non-structured content is difficult; third, the forms of integration supporting materials are not unified (such as interface documents, test reports), and the adaptability of the comparison rules is insufficient[7–8].

During the development process, the tool adopts a multi-technology integration solution; for video recording recognition, combining computer vision (CV) action recognition algorithms and speech-to-text technology, precise extraction of function nodes and software information; for multiple formats of files, through custom parsers to adapt to SQL, Excel, etc., combined with named entity recognition (NER) technology to extract key data; innovatively builds a "dynamic comparison rule engine", supporting flexible configuration of verification logic according to company architecture management requirement,and introducing version control mechanisms to ensure synchronization with the latest technical standards. This tool not only solves the pain points of "many materials, difficult verification, and low efficiency" in the online review stage, but also promotes the transformation of architecture review from "manual item-by-item verification" to "full-process intelligent verification", providing a reusable technical paradigm for the quality control of project launches in the energy industry, and also providing a reference for the collaborative verification of documents and multimedia content in similar fields.

4 Conclusion

This research targeted the challenges in the architecture control of the three key stages - feasibility study, design, and launch - during enterprise digital transformation, and developed and optimized a series of intelligent control tools. A complete process architecture control system was constructed. By integrating technologies such as BERT pre-training model, NER named entity recognition, and CV action recognition, the tools achieved compliance verification of feasibility study reports, extraction of architecture design information, cross-view comparison of summary design, and intelligent verification of launch materials, effectively solving problems such as low efficiency of traditional manual control, inconsistent data, and difficulty in managing assets. In practice, the tools have achieved remarkable results in multiple projects of State Grid across different regions: the feasibility study review cycle has been reduced from 7 days to 3 days, the efficiency of summary design review has increased by 50%, the launch review cycle has been halved, and the problem identification rate has reached 80%. This has ensured the consistency of system design with the enterprise strategy and the State Grid blueprint, reduced operation and maintenance costs and compliance risks, and provided strong support for digital transformation. The tools still face challenges such as deviation in non-structured text recognition, difficulty in adapting to multiple formats of files, and lag in standard updates. In the future, multi-modal large models can be introduced to improve recognition accuracy, a real-time rule library can be constructed, statistical analysis functions can be expanded, and the level of intelligence can be further strengthened. In summary, this tool promotes the transformation of the control mode from "human-centered" to "intelligence-driven", provides reusable technical paradigms for the energy industry, is of great significance for promoting standardization of architecture and improving resource utilization, and lays the foundation for the deepening of digital transformation.

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