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# Technical Management Strategy of Electrical Commissioning and Weak Current System Design for Environmental Protection Projects

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**Abstract:** Environmental protection projects face challenges in electrical commissioning and weak current system design, including multi-system coordination, extreme environment adaptation, and dynamic risk management. Guided by the Technical Specifications for Intelligent Buildings and Weak Current Systems (GB/T 50314-2023), this study proposes a full lifecycle management framework integrating redundant design, modular optimization, and IoT-based real-time monitoring. A fuzzy comprehensive evaluation model quantifies risk levels, enhancing system reliability and energy efficiency. BIM and data-driven methods optimize design-installation coordination, while dynamic data asset management and risk early warning systems improve operational robustness. Future research should focus on AI-driven automation and blockchain applications to advance intelligent and sustainable technical management.

**Keywords:** Environmental protection projects; Weak current system design; Technical management strategies

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## 1. Introduction

The rapid development of intelligent technologies has led to increasingly widespread applications of weak current systems in fields such as environmental protection, transportation, and architecture, with significant increases in complexity and integration. Particularly in environmental protection projects, technical management of electrical commissioning and weak current system design is crucial for energy efficiency, safety, and sustainability. However, challenges remain in multi-system collaboration, adaptability to extreme environments, and dynamic risk control. Taking subway weak current engineering as an example, its complex subsystem interfaces and frequent cross-construction easily lead to project delays and quality issues, urgently requiring optimization strategies. The Standard for Intelligent Building and Weak Current System Technology (GB/T 50314-2023) emphasizes full-life-cycle management, advocating modular design, redundant configuration, and data-driven risk early warning. However, existing research still shows deficiencies in dynamic data mining, multi-system collaboration, and intelligent decision-making. This paper integrates the IoT, fuzzy comprehensive evaluation, and BIM technology to explore innovative paths for technical management in environmental protection projects, aiming to provide theoretical support and solutions for engineering in complex environments.

## 2. Technical management strategies for electrical commissioning in environmental protection projects

### 2.1. Technical key points and management of PLC commissioning

PLC program logic verification and simulation testing are core links in ensuring the reliability of control systems. Logic verification requires item-by-item checking of input/output signals, interlock logic, and algorithm parameters in combination with process requirements. Simulation software should be used to build a virtual operating environment, simulating scenarios such as equipment start-stop and fault injection to verify program fault tolerance and response timeliness. In the simulation testing phase, hardware-in-the-loop (HIL) technology should be integrated, with real-time monitoring of signal status through the human-machine interface (HMI) to identify logic conflicts and communication delay issues. Standardized commissioning documentation requires the establishment of a unified template framework covering program comments, variable naming rules, commissioning record tables, etc., to ensure normative collaboration and traceability among multiple teams [1]. Version control strategies should rely on tools such as Git for program iteration management, clearly defining modification permissions and approval processes to avoid misoperation risks caused by version confusion during commissioning, while ensuring data security through cloud backups.

### 2.2. Collaborative management of electrical system commissioning

Linkage commissioning of high- and low-voltage equipment requires focused control of electrical parameter matching and harmonic interference risks. Before commissioning, the compatibility of rated parameters, protection settings, and grounding systems of high- and low-voltage equipment should be verified. Insulation resistance testers and power quality analyzers should be used to pre-inspect power supply circuits and identify potential overload or short-circuit hazards. During commissioning, multi-level interlock protection mechanisms should be set up, with real-time monitoring of current and voltage fluctuation data to dynamically adjust equipment operating thresholds. The dual-dimensional monitoring mechanism for progress and quality emphasizes the use of Gantt charts and critical path analysis as the basis, quantifying commissioning node completion rates and defect rate indicators, and generating commissioning reports through automated testing tools to achieve rapid positioning of progress deviations and dynamic resource allocation [2]. Quality control requires the establishment of standardized acceptance checklists covering core indicators such as insulation performance and functional response time, with regular cross-audits and data comparisons to ensure that commissioning results meet the energy efficiency and safety requirements of environmental protection projects.

## 3. Technical management strategies for weak current system design

### 3.1. Principles and optimization of weak current system design

Demand analysis for weak current systems in environmental scenarios should focus on energy consumption monitoring and environmental perception functions. Intelligent sensors and data acquisition terminals should be deployed to obtain key parameters such as equipment energy consumption, temperature and humidity, and pollutant concentration in real time, building a multi-source data fusion environmental perception network. Design optimization should follow modular principles, dividing the system into independent functional units (such as energy management and security communication), adopting standardized interface protocols and universal hardware platforms to reduce system coupling and enhance scalability. Compatibility assurance requires unified communication protocols (such as Modbus and BACnet) and open data interfaces to achieve interconnection of multiple subsystems, avoiding data barriers between heterogeneous devices, while combining redundant design and hot-swappable technology to ensure continuous system operation in the event of local failures.

### 3.2. Key technical management of weak current installation and commissioning

Communication network commissioning should be based on topology verification and signal strength testing, using network analyzers to locate abnormalities such as packet loss and delays, and formulating phased acceptance standards (such as physical layer connectivity testing and application layer protocol compatibility verification). Security system commissioning should focus on verifying the linkage logic of video surveillance, access control, and intrusion alarms, testing system response timeliness and alarm accuracy through simulated intrusion scenarios. BIM-based intelligent design methods emphasize integrating weak current equipment spatial layout and pipeline routing information in three-dimensional models, using collision detection functions to optimize wiring paths and reduce construction rework risks; at the same time, dynamic association of equipment parameters and commissioning data through the BIM platform provides visual data support for later operation and maintenance, improving full-life-cycle management efficiency [3].

## 4. Construction and implementation of technical management system

### 4.1. Full-life-cycle technical management framework

#### 4.1.1. Connection mechanism among design, installation, and commissioning phases

In the design phase, technical interface specifications and equipment selection standards should be clearly defined, with BIM technology used to achieve bidirectional mapping between three-dimensional models and electrical parameters, ensuring the implementability of design schemes. In the installation phase, construction plans should be formulated based on model data, RFID technology used to track equipment arrival and installation progress, and phased review meetings held to synchronize commissioning requirements. In the commissioning phase, a closed-loop verification process should be built based on design documents and installation records, with automated test scripts covering functional boundary conditions to ensure seamless connection of technical objectives across phases.

#### 4.1.2. Dynamic management of technical documents and data assets

Technical document management requires the establishment of unified coding rules and metadata tagging systems to achieve rapid retrieval and version tracing of drawings, program codes, and commissioning records. Dynamic management of data assets should rely on industrial internet platforms to integrate multi-source heterogeneous data (such as sensor data and operation logs), using data lake architecture for unified storage of structured and unstructured data [4]. Key data should be encrypted for transmission and regularly backed up to private clouds, with blockchain technology used to ensure data integrity and tamper resistance, while data analysis tools are utilized to mine historical data value and support technical decision optimization.

### 4.2. Personnel capability and team collaboration management

#### 4.2.1. Multi-disciplinary cross-training and skill certification system

Cross-disciplinary training should design course modules around the integration needs of electrical, weak current, and environmental processes, using virtual simulation platforms to simulate typical scenarios (such as PLC commissioning fault troubleshooting and weak current system interference analysis) to strengthen practical capabilities. The skill certification system should collaborate with industry associations to develop graded assessment standards covering theoretical tests, case analysis, and on-site operation evaluations, with dynamic updates to the certification question bank to match technological development trends [5]. Certification results should be linked to position promotion to incentivize continuous improvement of composite capabilities among technical personnel.

#### 4.2.2. Team collaboration optimization strategy based on PDCA cycle

Application of the PDCA cycle to team collaboration should be project-goal-oriented. In the Plan phase, tasks are decomposed via WBS and KPI indicators set; in the Do phase, agile management tools (such as Jira) are used for real-time tracking of task status and resource allocation. In the Check phase, weekly meetings are relied upon for root cause analysis of progress deviations and quality defects; in the Act phase, improvement plans are formed through optimization of process templates and resource allocation strategies [6]. Collaboration optimization requires the establishment of cross-departmental feedback mechanisms and the use of knowledge-sharing platforms to accumulate best practice cases, achieving spiral improvement in team collaboration efficiency.

## 5. Engineering risk management strategies for environmental protection projects

### 5.1. Risk identification and assessment methods

#### 5.1.1. Classification and quantification of risk sources in electrical and weak current systems

Risk sources faced by electrical and weak current systems in environmental protection projects can be divided into technical risks and environmental risks. Technical risks include electromagnetic interference, signal attenuation, insufficient equipment compatibility, and communication protocol conflicts; environmental risks involve temperature and humidity fluctuations, pollutant erosion, and mechanical vibration. Risk quantification requires the use of probability-impact matrices, determining risk occurrence probability and potential consequences through historical data analysis and simulation [7]. For example, electromagnetic interference can be measured for intensity using spectrum analyzers, with impact levels assessed based on equipment sensitivity thresholds; signal attenuation issues require mathematical models based on transmission distance, medium loss, and noise levels to quantify signal integrity loss. Risk quantification results can be mapped to a risk register, forming a dynamically updated risk database to provide data support for subsequent assessments.

#### 5.1.2. Risk level determination model based on fuzzy comprehensive evaluation method

The fuzzy comprehensive evaluation method addresses uncertainty in risk assessment by constructing a multi-level evaluation system. First, define the evaluation factor set covering technical parameters (such as interference intensity and signal stability), environmental conditions (such as temperature, humidity, and pollutant concentration), and management factors (such as commissioning process standardization). After that, use analytic hierarchy process (AHP) to determine factor weights, optimizing weight allocation with expert scoring and historical data. Membership function design should be based on risk characteristics, for example, using trapezoidal functions for electromagnetic interference risk to describe the nonlinear relationship between interference intensity and system failure probability [8]. Eventually, evaluation results are synthesized through fuzzy operators to output risk levels (low, medium, high). This model effectively handles the fusion of subjective judgment and objective data, improving the scientificity and operability of risk determination.

## 5.2. Risk response and control measures

### 5.2.1. Redundant design and emergency plan formulation in commissioning phase

Redundant design enhances system fault tolerance by adding backup systems or key components, such as dual power supplies, hot-standby PLC modules, and parallel communication links. In the commissioning phase, fault tree analysis (FTA) should be used to identify single-point failure risks and deploy redundant architectures accordingly. Emergency plans should be formulated based on risk scenario simulations, clearly defining fault diagnosis processes, emergency switching mechanisms, and personnel divisions. For example, for communication interruption risks, automatic switching to backup network protocols should be preset, with offline caching to ensure data continuity [9]. Plan drills should combine virtual simulation platforms to verify response timeliness and operational feasibility, forming standardized emergency operation manuals through iterative optimization.

### 5.2.2. Application of anti-interference technology in weak current systems

Anti-interference technology for weak current systems requires coordinated optimization from hardware design and signal transmission aspects. At the hardware level, shielding and grounding techniques should be adopted to reduce electromagnetic interference, using multi-layer shielded cables, metal conduits, and equipotential connections to minimize common-mode noise. Optical fiber communication technology can replace traditional copper cables, utilizing the anti-electromagnetic interference characteristics of optical signals to ensure long-distance transmission stability. At the signal processing level, differential signal transmission, digital filtering, and error checking mechanisms should be introduced to suppress high-frequency noise and data packet loss. For example, in energy consumption monitoring systems, combining optical fiber communication with Modbus TCP protocol achieves reliable data transmission in high-noise environments. Technology application should be verified through on-site testing to ensure system robustness in complex environments.

## 5.3. Continuous improvement of risk management

### 5.3.1. Construction of risk database and historical case learning mechanism

Risk database construction requires structured data models to integrate multi-source data from electrical commissioning, weak current system operation, and environmental monitoring, covering fields such as risk event type, occurrence frequency, impact degree, and disposal measures. Data standardization adopts unified coding rules and metadata tagging systems to support multi-dimensional retrieval and association analysis. The historical case learning mechanism establishes a case library to record typical risk events (such as control failures caused by signal attenuation), using natural language processing technology to extract case features and solutions, forming a knowledge graph. Regular case reviews and cross-project comparative analyses identify risk evolution patterns and common defects, optimizing risk prediction models through machine learning algorithms to enhance the targeting and foresight of risk response strategies. The database dynamic update mechanism should interface with the project full-life-cycle management platform for real-time data synchronization and version tracing [10].

### 5.3.2. Real-time risk monitoring and early warning system based on IoT

The application of IoT technology focuses on building distributed sensor networks for real-time collection of electrical parameters, weak current signal quality, and environmental status. Data is preprocessed at edge computing nodes to filter noise and extract key features before upload to the cloud risk analysis platform. The platform uses time-series databases for data storage, combining fuzzy logic and neural network algorithms to establish risk prediction models for dynamic assessment of system health. The early warning system generates graded alarms based on preset thresholds and model outputs, pushing information through visual interfaces and mobile terminals. The system integrates automated response functions, such as automatically activating shielding grounding devices or switching to redundant communication links when electromagnetic interference exceeds limits. Technology verification requires simulated extreme environment testing to ensure monitoring accuracy and warning timeliness, providing real-time decision support for risk management.

## 6. Conclusion

Environmental protection projects have improved control system reliability and energy efficiency through PLC logic verification, redundant design, and modular optimization. Weak current systems adopt multi-source data fusion and standardized interface protocols to reduce coupling and enhance environmental perception. Full-life-cycle technical management, combined with dynamic data asset management, ensures efficient connection among design, installation, and commissioning. Fuzzy comprehensive evaluation models are used to quantify risks, with IoT monitoring and early warning systems achieving dynamic control. Although existing strategies are effective, deficiencies remain in extreme environment adaptability and multi-system collaboration depth, with needs for improvement in historical data mining and dynamic prediction accuracy. Future research should focus on AI-driven automated commissioning technologies to optimize fault diagnosis and parameter self-adjustment; explore blockchain for secure data sharing, combined with digital twins to build virtual-real fusion simulation platforms, promoting intelligent, digital, and sustainable development.

## Disclosure statement

The author declares no conflict of interest.

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