

PCI Smart Station Technical Proposal

I. Requirements Background and Business Pain Points

1.1 Operational Pressure Amid Network Scale Expansion

As urban rail transit enters the networked operation phase, the management philosophy is gradually shifting from non-market-oriented to market-oriented, and the operational pressure brought by network scale expansion is becoming increasingly prominent. The core characteristics of smart metro in the new era are concentrated in six dimensions: "safety, reliability, convenience, precision, greenness, and sustainability." However, the existing operation system has varying degrees of shortcomings in all six dimensions.

From the perspective of system collaboration, various automation systems have been built independently for a long time, forming numerous data silos with low data integration and poor interoperability. The response speed of cross-system linkage can hardly meet the requirements of networked operation. Metro projects typically involve multi-vendor, multi-standard equipment integration with complex system interfaces, further increasing the difficulty of data integration and collaborative linkage. From the perspective of cost control, labor costs account for a persistently high proportion of total operating expenditure, with labor costs being particularly prominent; energy costs continue to rise, and routine equipment maintenance as well as major and intermediate overhaul costs increase year by year as line mileage extends. Meanwhile, the fully outsourced model brings significant management liability risks to operating enterprises. From the perspective of equipment maintenance, the workload during major overhaul periods is enormous; project equipment comes from diverse brands with long procurement cycles for spare parts, making it difficult to strike a balance between cost savings and mastery of core technologies.

1.2 Prominent Contradictions in Existing Station Operation Management

1.2.1 Insufficient Operational Safety Prevention and Control Measures

Safety prevention and control at existing stations still relies primarily on manual patrols and passive response, with weak capabilities in proactive perception and early warning. Equipment abnormal alarm information is scattered across independent systems of various disciplines. Duty personnel need to switch between multiple systems to grasp the overall safety situation of the station, and there are delays in the aggregation and transmission of abnormal information. Metro safety compliance requirements are strict, and emergency response procedures need to be standardized and traceable. However, current emergency plan management relies on paper documents and personnel experience, making it difficult to ensure response consistency across different stations and shifts.

In terms of equipment safety, the operating status of critical equipment lacks centralized monitoring means. Equipment abnormalities are often only discovered after a fault occurs, lacking early warning capability. Video surveillance relies primarily on manual monitoring; duty personnel need to simultaneously monitor dozens of surveillance feeds, which easily leads to missed views and oversights, making it difficult to guarantee patrol quality and coverage.

1.2.2 Urgent Need to Improve Operational Control Efficiency

Pre-operation inspections at stations and along lines are inefficient. Taking a line with multiple stations as an example, the train dispatcher on duty needs to verify the date and clock time with each station's duty personnel one by one every day, resulting in a heavy workload; station duty personnel also need to report pre-operation inspection results to the train dispatcher one by one, with low communication efficiency. More critically, manual inspections can only observe surface conditions and are prone to oversights, making inspection quality difficult to guarantee.

Production and operation data is obtained inefficiently and untimely; duty personnel and management need to log into multiple systems to piece together the overall station operation situation, which can hardly support rapid decision-making. Station staffing is lean, and duty personnel typically need to simultaneously undertake multiple responsibilities such as train dispatching, passenger transport, and equipment monitoring. The burden of switching between multiple systems is heavy, and information acquisition efficiency directly affects operational control quality. Station opening and closing operations involve multiple types of equipment such as entrance/exit rolling shutters, escalators, environmental control ventilation, and lighting. Currently, these rely on manual item-by-item execution according to operation orders, with cumbersome procedures that are prone to omissions.

1.2.3 Low Efficiency in Multi-System Collaborative Operations

Metro projects typically integrate automation systems from multiple vendors. Each discipline's system is built and operated independently, and station duty personnel need to switch between multiple workstations to complete daily operational tasks. Scenarios such as station opening/closing, pre-operation inspections, and emergency response involve collaborative operation of multi-discipline equipment. Currently, there is a lack of automatic linkage between systems, with scattered operation steps, low execution efficiency, and a high risk of omissions.

Operation management covers multiple scenarios including operation preparation, station opening, peak-hour monitoring, off-peak monitoring, construction monitoring, station closing, and nighttime clearance patrols. Each scenario involves collaborative operation of multiple discipline systems. Currently, business is executed on multiple terminals, with each discipline system operated independently, requiring duty personnel to switch between multiple workstations; manual patrols are dominant, with equipment patrols, environmental patrols, and safety patrols all relying on personnel walking, making patrol quality and coverage difficult to guarantee; paper-based ledgers are still widely used for operation information release, shift handover records, and patrol records, resulting in slow information flow, difficult queries, and inconvenient statistical analysis.

High-density, highly random operation scenarios, unpredictable human factors, and dynamic risk factors result in insufficient capabilities of the existing operation system in early perception, anticipation, prediction, and warning. When abnormal situations occur, the system is often in a passive response state and cannot achieve proactive prevention and control.

1.2.4 Backward Daily Operation Management Methods

Daily station operation covers multiple scenarios including operation preparation, station opening, peak-hour monitoring, off-peak monitoring, construction monitoring, station closing, and nighttime clearance patrols. Each scenario involves collaborative operation of multiple discipline systems. Current operation management has three prominent problems: first, business is executed on multiple terminals, with each discipline system operated independently, requiring duty personnel to switch between multiple workstations; second, manual patrols are dominant, with equipment patrols, environmental patrols, and safety patrols all relying on personnel walking, making patrol quality and coverage difficult to guarantee; third, paper-based ledgers are still widely used for operation information release, shift handover records, and patrol records, resulting in slow information flow, difficult queries, and inconvenient statistical analysis.

With lean station staffing, daily operation management relies more heavily on automation and informatization tools. Manual patrols and paper-based ledgers can hardly meet the operation management requirements under the lean-staffing model.

1.2.5 Intelligent O&M System Not Yet Established

O&M work lacks a comprehensive management platform; each discipline's O&M system operates independently with data that cannot be shared, and O&M decisions lack data support. Metro equipment comes from diverse brands with complex system interfaces; O&M management for electromechanical, communications, and other discipline equipment is fragmented, lacking a unified monitoring and analysis platform. The O&M management efficiency of key systems such as PSD, AFC, HVAC/water/electrical, integrated supervisory control, and communications is relatively

low. Equipment O&M methods are single-dimensional with a low degree of intelligence, still relying primarily on scheduled maintenance and post-fault repair, lacking capabilities for condition-based maintenance and predictive maintenance.

Equipment health status lacks quantitative assessment means; O&M personnel cannot accurately grasp the actual operating status of equipment, and maintenance plans can only be executed according to fixed cycles, resulting in the coexistence of over-maintenance and under-maintenance. Fault troubleshooting relies on personnel experience, with step-by-step testing and segment-by-segment localization taking a long time, making fault repair efficiency difficult to guarantee.

1.3 Analysis of Pain Points in Typical Scenarios

1.3.1 Pre-Operation Inspection: Cumbersome Process, Prone to Omissions

Stations require pre-operation inspections to be completed before daily opening. Inspection contents include confirming the completion of line construction, checking line clearance and foreign object intrusion, operating the PSL panel to inspect platform screen doors, conducting turnout tests, checking the status of systems such as FAS/ISCS/environmental control/AFC, turning on PIS displays, verifying date and clock time with the train dispatcher one by one, and reporting pre-operation inspection results to the train dispatcher one by one—more than ten tasks in total, which are prone to omissions. With few station duty personnel, numerous pre-operation inspection items, and long procedures, manual item-by-item execution is inefficient and quality is difficult to guarantee.

1.3.2 Equipment Faults: Manual Troubleshooting, Difficult Localization

Taking the PSD system as an example, key indicators such as sliding door operating status and power cabinet parameters lack centralized monitoring. Equipment abnormalities are often only discovered after passenger complaints or fault occurrence, and fault troubleshooting requires O&M personnel to conduct on-site tests one by one, taking a long time for localization. AFC equipment operating status is scattered across

various terminals, with delayed fault discovery that affects passenger passage experience. HVAC/water/electrical equipment operating parameters lack real-time monitoring, and problems such as abnormal pump start/stop and inefficient air conditioning operation are difficult to identify in a timely manner.

Communications system equipment is diverse in type, with video surveillance, power, transmission, broadcasting, clock, and other discipline equipment operating independently. Equipment fault alarms are scattered, and O&M personnel need to switch between multiple systems to locate the fault source, resulting in low fault troubleshooting efficiency. End-to-end fault localization relies on personnel experience, with step-by-step testing and segment-by-segment investigation taking a long time.

1.3.3 Equipment Hidden Hazards: Manual Patrol, Delayed Discovery

Daily equipment patrols rely on personnel walking, with fixed patrol routes and long patrol cycles, making it difficult to detect abnormal equipment status in a timely manner. Taking HVAC/water/electrical equipment as an example, hidden hazards such as frequent pump startups and abnormal air conditioning operating parameters are often only noticed after equipment failure or abnormal energy consumption increases, lacking early warning capability.

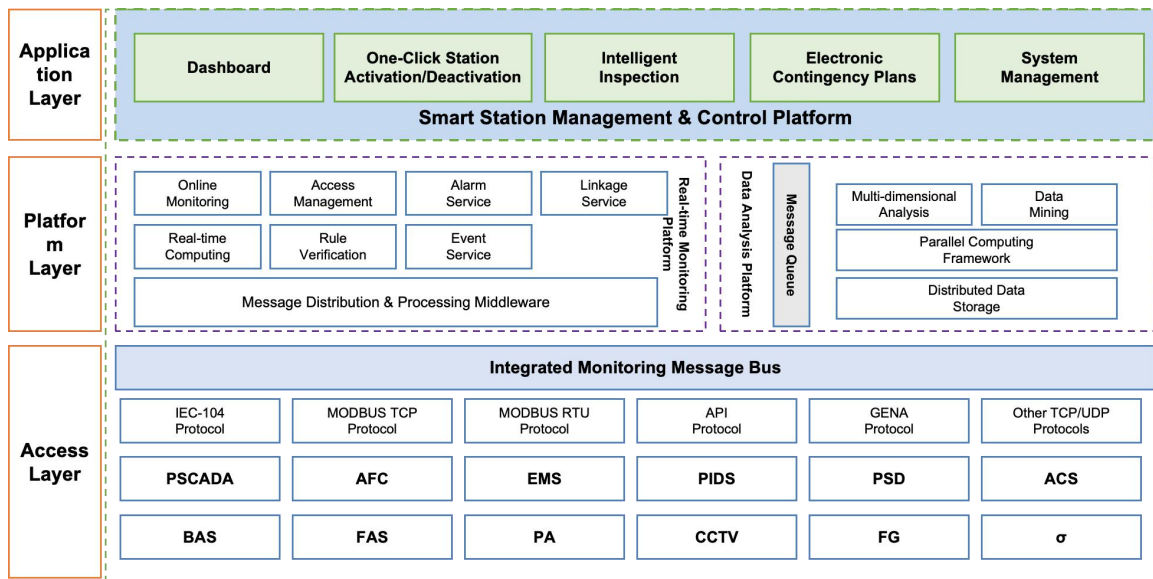
Equipment health status lacks quantitative assessment; O&M personnel cannot accurately grasp the degree of equipment aging and potential fault risks, and maintenance plans can only be executed according to fixed cycles, resulting in the coexistence of over-maintenance and under-maintenance. The O&M team is limited in size, and equipment hidden hazard investigation relies heavily on personnel experience and sense of responsibility, with a relatively high risk of missed or delayed inspections.

II. Overall Solution Architecture

2.1 Overall Architecture of the Smart Station Control Platform

The overall architecture of the Smart Station Control Platform comprises four parts: the access layer, platform layer, application layer, and human-machine interface layer. The Smart Station Control Platform is located at the application layer of the system architecture.

The system architecture diagram of the Smart Station Control Platform is shown below:



Overall Architecture of the Smart Station Control Platform

The Integrated Supervisory Control System (ISCS) and the Smart Station Control Platform can be integrated through data interface and data processing layer reuse. The human-machine interface adopts a common C/S client framework embedded with B/S applications to achieve system fusion. The project can achieve unified integration based on the platform capabilities of both the ISCS and the Smart Station Control Platform, realizing data access and business logic processing for integrated and interconnected subsystems, and uniformly providing business services to upper-layer applications. It can

also connect to other external services through platform capabilities, further enhancing the service support of the ISCS and the Smart Station Control Platform.

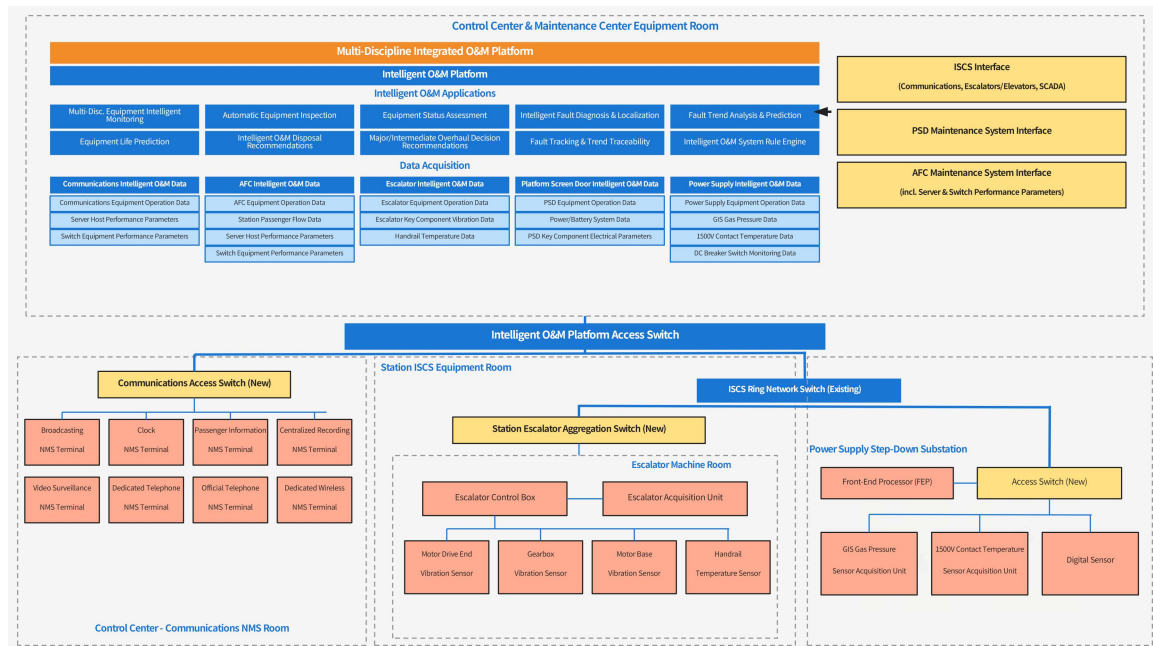
2.2 Overall Architecture of the Integrated O&M Platform

The overall architecture of the Integrated O&M Platform is divided into three parts: central application services, central data interfaces, and station-side data acquisition. Built on the central platform data foundation, it integrates multi-discipline intelligent O&M subsystems including communications, AFC, platform screen doors, integrated supervisory control, escalators and elevators, and power supply, forming a unified multi-discipline integrated O&M system and achieving layered decoupling between bottom-layer data acquisition and upper-layer business applications.

Taking the Integrated O&M Platform project of Changsha Line 6 Smart Metro as an example, the system acquires multi-discipline equipment data through a combination of central interface docking and on-site station acquisition. On the central side, existing ISCS, PSD maintenance, and AFC maintenance systems are accessed through standardized interfaces to read existing equipment operation, alarm, and other legacy data from each discipline. On the station side, new acquisition links are added to collect performance parameters of communications discipline servers and switches, while simultaneously accessing real-time data from newly installed vibration and temperature sensors on escalators/elevators, as well as front-end sensors such as GIS gas pressure and contact temperature in the power supply discipline. Various on-site acquisition data is uniformly uploaded to the central platform data acquisition layer via new and existing station switches and backbone network channels for aggregation, cleaning, and standardization processing.

The central platform application service module carries the full range of intelligent O&M business capabilities, covering multi-discipline equipment intelligent monitoring, automatic equipment inspection, equipment status assessment, intelligent fault diagnosis and localization, fault trend analysis and prediction, equipment life prediction, O&M disposal and major overhaul plan management, fault traceability and rule engine, and

other functions. The system integrates vertical domain large language models for each discipline to build an equipment status assessment system. Based on individual equipment operating parameters, maintenance and fault histories, it mines hidden hazards and outputs phased maintenance disposal recommendations. It is also equipped with a fault disposal knowledge base and an intelligent O&M Q&A assistant, supporting frontline personnel to retrieve fault disposal solutions at any time, empowering on-site O&M operations. This achieves full-process integrated management from equipment monitoring, hazard analysis, and work order triggering to O&M closed-loop, improving overall line O&M efficiency and fault disposal levels.



III. Solution Functions and Key Features

3.1 Smart Station Functions and Key Features

3.1.1 Comprehensive Dashboard

3.1.1.1 Station Equipment Overview.

The Station Equipment Overview presents the overall situation of station passenger transport management and equipment operation management through a data visualization comprehensive dashboard and integrates with business systems such as passenger transport organization, passenger services, and train dispatching to dynamically monitor station operation management business. After processing and converting the collected data, the system intuitively displays operation data such as passenger flow, equipment, and train dispatching in the form of tables, graphs, and data, helping operation personnel quickly grasp the station operation situation, reducing multi-system switching, and improving operation monitoring and decision-making efficiency.

3.1.1.2 Passenger Transport Management

Passenger Transport Management intuitively displays station passenger flow conditions through entry/exit passenger flow figures, passenger flow trend curves, and train car crowding models. Specific data makes entry/exit passenger flow clear at a glance; curve change graphs reflect real-time passenger flow trends; the train model uses different passenger counts and colors to show the crowding situation of upcoming up/down direction train cars. Based on this, operation personnel can identify crowding risks in advance and provide services to passengers at the earliest opportunity, improving passenger transport organization efficiency.

3.1.1.3 Environmental Compliance Rate and Distribution

Environmental Compliance Rate and Distribution models sensors for temperature, humidity, CO₂, PM_{2.5}, and PM₁₀ in station public areas and places them according to actual positions, forming the visualization foundation for environmental monitoring. The system distinguishes compliance status by setting sensor value ranges and POI colors, and displays the compliance rate of various types of equipment through visualization charts.

3.1.1.4 Train Information Monitoring

Train Information Monitoring centrally displays train arrival information at the current station, including train number, up/down direction information, next station information, as well as crowding information for the current train, next train, and third train in the up/down direction, following passenger flow monitoring display rules. The 3D model simultaneously displays sliding door open, close, and fault status, and shows entry/exit animations based on vehicle arrival information. Centrally presenting train information, passenger flow crowding, and platform equipment status helps operation personnel grasp train arrival rhythm and platform organization conditions.

3.1.1.5 Fault Overview

The Fault Overview classifies and counts faults by subsystems such as platform screen door equipment, ventilation and air conditioning equipment, vertical elevators and escalators, and performs total count and proportion analysis through charts, while supporting weekly, monthly, and yearly dimension filtering. This helps grasp fault-concentrated areas and change patterns, providing a basis for maintenance plans, resource allocation, and system optimization.

3.1.1.6 Station 3D Panorama

The Station 3D Panorama is based on 3D models of the station and equipment. By binding real equipment numbers for point data communication, it restores a 1:1 station in 3D. The system connects to the backend server and subscribes to equipment data points; upon subscription, it immediately returns current values, and when values change, the server pushes them to the 3D system, which determines the real-time equipment status accordingly.

3.1.2.7 Alarm Manager

The Alarm Manager supports displaying status overviews in two list forms: alarm logs and event logs. Event/alarm logs record status changes, alarms, controls, configurations, and modifications of all equipment by time. The system also provides dynamic screens of all monitored equipment. This achieves centralized viewing and

traceability of equipment status, alarm events, and operation records, facilitating rapid response by duty personnel and subsequent analysis.

3.1.2 One-Click Station Opening/Closing

One-Click Station Opening/Closing solidifies the linkage operations of various systems during station opening/closing into automated, rationalized, and procedural emergency plans. After activation, the platform issues control commands to each system, which turn on the corresponding equipment and feed back operating status in real time to the Smart Station subsystem backend. The linkage scope includes BAS environmental control mode, escalator/elevator operation mode, vertical elevator operation mode, rolling shutter control, as well as PA station opening broadcast, PIS station opening display, PSD door open/close self-test, AFC mode control, smart lighting mode switching, and CCTV screen confirmation. Station personnel can complete station opening work in a timely manner based on equipment feedback, reducing manual item-by-item operations and improving opening efficiency, standardization, and consistency.

3.1.3 Video Inspection Patrol

Video Inspection Patrol provides automated inspection functionality, supporting video inspection of the station according to specified video inspection routes. In route planning, the user manually selects a pre-configured video inspection route and starts the task. The system retrieves corresponding surveillance feeds in camera order, with each feed's dwell time executed according to the duration set in the inspection route. When inspection personnel discover equipment abnormalities, they can pause the task and record the abnormality, or resume the paused task at any time to complete a full inspection. Through the linkage between video inspection and the 3D scene, inspection coverage and efficiency can be improved, facilitating the discovery, recording, and closed-loop handling of abnormalities.

3.1.4 Equipment Inspection Patrol

The Equipment Inspection function supports users in manually selecting a pre-configured equipment inspection route and starting the inspection task. The system retrieves real-time panel data of corresponding equipment in the configured equipment order, facilitating inspection personnel in observing the current equipment status. When inspection personnel discover equipment abnormalities, they can pause the inspection task and record the abnormality, or resume the paused task at any time to complete a full inspection. The system also supports providing abnormal equipment events or faults monitored by the integrated supervisory control alarm module. This function combines inspection routes, real-time panel data, and abnormality records to improve equipment inspection standardization and O&M response efficiency.

3.1.5 Electronic Emergency Response Plans

When an emergency event actually occurs, staff can rely on the system to quickly launch the corresponding emergency response plan. The system guides response personnel through item-by-item confirmation and operation according to pre-arranged content. The interface intuitively displays the event name, response process, and relevant personnel involved. The bottom integrates commonly used emergency unit contact information such as passenger emergency intercom phones, police phones, medical emergency phones, and operation control center phones. This ensures that no key information or steps are omitted during the response process, and also facilitates command personnel in quickly obtaining contact information under emergency conditions, improving emergency response efficiency.

3.2 Intelligent Analysis System Functions and Key Features

3.2.1 Platform Screen Door Intelligent O&M

Platform Screen Door Intelligent O&M provides line-level and station-level two-tier visualization homepages, achieving integrated monitoring from the entire line to individual station equipment. It configures a key component dashboard to conduct

parameter monitoring, health scoring, and hazard warning for four core components including the DCU door controller and drive motor. It builds a power system monitoring dashboard supporting one-click intelligent inspection to replace manual on-site inspection. Through action record analysis, it collects full digital and analog data during door opening/closing, verifies action timing, locates command and transmission faults, and supports predictive maintenance. Relying on the data statistics analysis module, it counts alarms, fault rankings, and equipment health, intuitively assessing the operation situation of platform screen doors across the line and providing data support for O&M decisions.

3.2.2 AFC Intelligent O&M

AFC Intelligent O&M realizes centralized monitoring of terminal equipment such as turnstiles and TVMs, as well as network links, through a visualization network topology homepage, supporting partitioned viewing and custom topology configuration.

Equipment module-level monitoring realizes visualization of internal component status of turnstiles and ticket vending machines, completing component-level fault localization. The intelligent statistics analysis and decision module counts equipment reliability at a 15-minute acquisition granularity, calculates MTBF indicators, builds a maintenance priority matrix, and outputs preventive maintenance recommendations. It also analyzes turnstile usage frequency, provides equipment load balancing optimization strategies, and automatically generates multi-cycle O&M reports, driving the O&M model to shift from passive emergency repair to proactive prevention.

3.2.3 Communications Intelligent O&M

The Communications Intelligent O&M homepage aggregates multi-dimensional dashboards such as alarm statistics and fault rankings, visually displaying the alarm situation of all stations along the line and achieving centralized monitoring and disposal of communications faults. The equipment monitoring function integrates cabinet simulation and network topology monitoring, covering multiple communications subsystems such as video surveillance, train-ground wireless, and dedicated transmission, collecting real-time equipment parameters and supporting historical data traceability.

End-to-end intelligent analysis builds a full-service link topology, achieving alarm normalization and aggregation, and completing fault traceability and localization. Wireless performance intelligent analysis collects wayside and onboard AP signal strength, identifies signal weak points through charts, and proactively investigates signal attenuation hazards, ensuring stable operation of the train-ground wireless communication link.

3.2.4 Integrated Supervisory Control System Intelligent O&M

Integrated Supervisory Control System Intelligent O&M comprises two major capabilities: host equipment performance detection and equipment status assessment. Host equipment performance detection fills the gap in underlying infrastructure monitoring, collecting hardware resources, network links, and program operation indicators for servers, FEP hosts, core switches, and dispatcher workstations, to proactively identify platform operation hazards. Equipment status assessment relies on electromechanical equipment start/stop sequences, analog/digital values, operating hours, and maintenance work orders to build a multi-dimensional health analysis model, aggregating multi-cycle operation data, comparing load changes under different operation scenarios, identifying component aging and hidden faults, and providing early warnings for equipment such as environmental control, escalators/elevators, and platform screen doors, to avoid disruption to operations caused by sudden equipment failure.

3.2.5 Escalator and Elevator Intelligent O&M

Escalator and Elevator Intelligent O&M adapts to scenarios with a large number of equipment and high manual inspection pressure. The equipment monitoring module continuously collects component operating parameters and implements graded alarms based on dynamic thresholds and a three-level risk warning system, supporting remote fault troubleshooting. Intelligent analysis and diagnosis integrates conventional, medium-low frequency, and vibration-noise high-frequency data, and through multiple rounds of signal processing and fault feature matching, calculates fault probability at the whole-machine, module, and component levels to achieve fault prediction. Trend traceability

allows viewing real-time and historical measurement point curves, with baselines supporting algorithmic adaptive adjustment, facilitating data review during abnormal periods. Spectrum analysis uses time-frequency domain, envelope demodulation, and other signal processing methods to display vibration spectra, supporting custom fault marker lines and assisting experts in manual fault diagnosis.

IV. Solution Advantages

4.1 Improved Operational Safety Assurance Capability

Smart station construction centers on the core objective of operational safety, driving the safety control model to achieve three transformations. First, the transformation from manual command to digital command: the comprehensive dashboard centrally displays station equipment status, alarm information, and environmental parameters, allowing duty personnel to grasp the overall station operation situation without switching between multiple systems, reducing safety risks caused by human judgment errors. Second, the transformation from passive response to proactive disposal: the alarm manager pushes equipment abnormal information in real time, and electronic emergency plans pre-configure standardized response procedures by event type. After an event is triggered, the corresponding plan can be quickly retrieved and related equipment linked, shortening the response time from discovery to disposal. Third, the transformation from human prevention to technical prevention for key risks: video inspection and equipment inspection are automatically executed according to preset routes, replacing manual timed patrols of key areas and equipment, reducing safety hazards caused by missed inspections and fatigue operations.

4.2 Improved Operation Management Efficiency

4.2.1 One-Click Station Opening/Closing

Traditional station opening/closing operations require duty personnel to execute item by item according to operation procedures, involving multiple types of equipment such as

entrance/exit rolling shutters, escalators, environmental control ventilation, and lighting, with cumbersome operation procedures that are prone to omissions. The one-click station opening and one-click station closing functions solidify the opening/closing process into standardized plans. A single operation can link all station equipment to execute in sequence, and opening/closing records automatically retain operation time and execution results. Station opening/closing operation time is significantly shortened, and operation standardization and traceability are simultaneously improved.

4.2.2 Intelligent Inspection

Video inspection supports custom inspection routes and camera configurations, automatically executing inspection tasks according to schedules and retaining historical records, replacing manual timed video patrols of public areas such as station halls, platforms, and entrances/exits. Equipment inspection supports custom inspection equipment lists, automatically querying equipment operating status and outputting inspection results, replacing manual transcription and on-site confirmation. Used in combination, the two types of inspection functions can cover daily patrol needs for station public areas and major equipment, with the inspection range coverable per unit time greatly increased.

4.2.3 Comprehensive Dashboard Centralized Monitoring

The comprehensive dashboard integrates station equipment overview, passenger flow information, signal data, BAS environmental information, and the alarm manager into a single interface. Station building structure and equipment models are displayed graphically, with equipment status updated in real time; real-time entry/exit passenger flow counts and cumulative passenger flow data are presented intuitively; the arrival/departure time of the most recent train is displayed synchronously; station hall and platform temperature/humidity and CO2 concentration are monitored in real time; currently alarming equipment data is centrally displayed. Duty personnel can grasp the overall station operation status without logging into multiple systems, with information acquisition efficiency and decision response speed simultaneously improved.

4.2.4 Standardized Disposal via Electronic Emergency Plans

Electronic emergency plans support configuring different plan contents by event type, covering typical scenarios such as equipment faults, fire linkage, and abnormal passenger flow. When an event occurs, duty personnel can quickly retrieve the corresponding plan and execute according to the response steps specified in the plan, with historical activation records automatically retained. Plan management solidifies emergency response experience scattered across various positions into standardized procedures, allowing new employees to quickly get started, maintaining consistent response standardization across different stations and shifts, and avoiding improper response caused by differences in personnel experience.

4.3 Multi-Discipline Integrated O&M Platform and Large-Model-Based Equipment Status Assessment System

4.3.1 Multi-Discipline Integrated O&M Platform

The intelligent O&M system builds a multi-discipline integrated O&M platform that, relying on a unified data foundation, can access equipment operation data from multiple disciplines including platform screen doors, AFC, communications, escalators/elevators, and integrated supervisory control. The platform can link with business management systems such as O&M production plans, work orders, and materials, breaking down barriers between data and business processes. It builds full-chain capabilities covering equipment status monitoring, intelligent hazard analysis, automatic fault work order triggering, and business process closed-loop control, achieving integrated O&M management of multi-discipline equipment, breaking down data silos across discipline systems, and improving the overall metro O&M coordination and management level.

4.3.2 Large-Model-Based Equipment Status Assessment System

The system builds a standardized equipment status assessment system based on vertical domain large language models for each discipline. Combining real-time operating data of individual equipment, maintenance records, and fault histories to conduct in-depth

analysis, it mines potential hidden hazards such as equipment performance degradation and component aging, comprehensively evaluates equipment health levels, and outputs targeted phased maintenance and fault disposal recommendations. This achieves the transformation from post-event emergency repair to predictive maintenance, effectively reducing the risks posed by sudden equipment failures to metro operations.

Relying on vertical domain large model capabilities, the platform equips each discipline with functional modules such as fault disposal guides and intelligent O&M assistants, supporting O&M personnel with work order disposal guidance and flexible Q&A interaction. It provides convenient knowledge query and fault consulting services for dispatchers and on-site maintenance personnel, empowering frontline operators to quickly understand fault causes and master disposal key points, shortening fault assessment and disposal time, and further improving the flexibility, work efficiency, and service quality of metro integrated O&M disposal.

V. Main Product Introduction

5.1 Smart Station Control Platform

5.1.1 User Authentication

5.1.1.1 User Permission Platform

According to unified authentication and authorization requirements, it provides functions such as user management, identity authentication and authorization, and user permission management for application subsystems in metro business systems. Main functions include permission management, account login (supporting switching between multiple login methods), system menu management, user information details, user profile modification, user management, role management, resource group management, resource management, system management, security settings, and log management.

5.1.2 Comprehensive Dashboard

5.1.2.1 Station Equipment Overview

The Smart Station Control Platform is equipped with a comprehensive dashboard interface with data visualization functions to intuitively reflect the overall situation of station passenger transport management and equipment operation management. It organically integrates with other business systems within the station such as passenger transport organization, passenger services, and train dispatching, dynamically monitoring station operation management business.

The system processes and converts collected data, and intuitively displays analyzed and processed operation data such as passenger flow, equipment, and train dispatching in the form of tables, graphs, and data for station passenger transport management.

5.1.2.2 Passenger Flow Management

Specific data figures reflect station entry/exit passenger flow, clear at a glance; curve change graphs show passenger flow trends, allowing real-time grasp of passenger flow changes; in the train model, different passenger counts and colors vividly show the crowding situation of upcoming up/down direction train cars at the station, facilitating operation personnel to provide services to passengers at the earliest opportunity.

5.1.2.3 Environmental Compliance Rate and Distribution

1. Model temperature sensors, humidity sensors, CO2 sensors, PM2.5 sensors, and PM10 sensors in station public areas and place them according to actual positions.

2. Set value ranges for various sensors and define corresponding POI colors: non-compliant items are displayed in yellow, compliant items in blue. Through visualization charts, distinguish whether items are compliant and display the compliance rate of various types of equipment.

Click on the compliance rate statistics value of corresponding equipment to display a list of all equipment under that category and show the actual value of each equipment. Double-click the equipment name to fly to that equipment in the 3D scene to understand its specific location.

5.1.2.4 Train Information Monitoring

1. Through visualization charts, monitor train arrival information at the current station: train number, up/down direction information, next station information;
2. The interface supports displaying crowding information for the current train, next train, and third train in the station's up/down direction, following passenger flow monitoring display rules.
3. Display the corresponding status of sliding doors in the model, showing sliding door open, close, and fault status;
4. Based on vehicle arrival information, display entry/exit animations on the 3D model.

5.1.2.5 Fault Overview

Classify and count by subsystems (including platform screen door equipment, ventilation and air conditioning equipment, vertical elevators and escalators), and perform total count and proportion analysis through charts, achieving weekly, monthly, and yearly dimension filtering.

5.1.2.6 Station 3D Panorama

Based on 3D models of the station and equipment, by binding real equipment numbers and using these numbers for point data communication, it completes the monitoring function for station equipment status. The station building structure mainly includes the station hall level, platform level, tunnels, entrances/exits and passages, and equipment rooms. Equipment mainly includes escalators, elevators, CCTV, turnstiles, ticket vending machines, etc. The system restores a 1:1 station in 3D. Based on the 3D

scene, it connects to the backend server and subscribes to equipment data points, immediately returning current values upon subscription. When point values change, the server pushes the changed values to the 3D system, which performs logical judgment based on the latest point values to determine whether the equipment is in one of four states: communication abnormality, normal operation, equipment alarm, or equipment fault, expressed by changing the appearance of the equipment model.

Equipment status includes business status and non-business status. Non-business status is mainly the outer contour, which is displayed when the mouse hovers over the equipment, indicating that the equipment is interactive; selecting the equipment outer contour produces a breathing light effect. Real-time equipment status is expressed by changing the model's appearance: normal operation is indicated in green, alarms in yellow, and faults in red. The appearance of the equipment model changes in real time as real-time data updates. For some special data points, such as platform screen door open/close, turnstile open/close, and escalator up/down direction, they are associated with animations in the 3D model. When a platform screen door opens in reality, the model also executes the door opening action. By binding train entry/exit signals, train entry and exit animations are achieved.

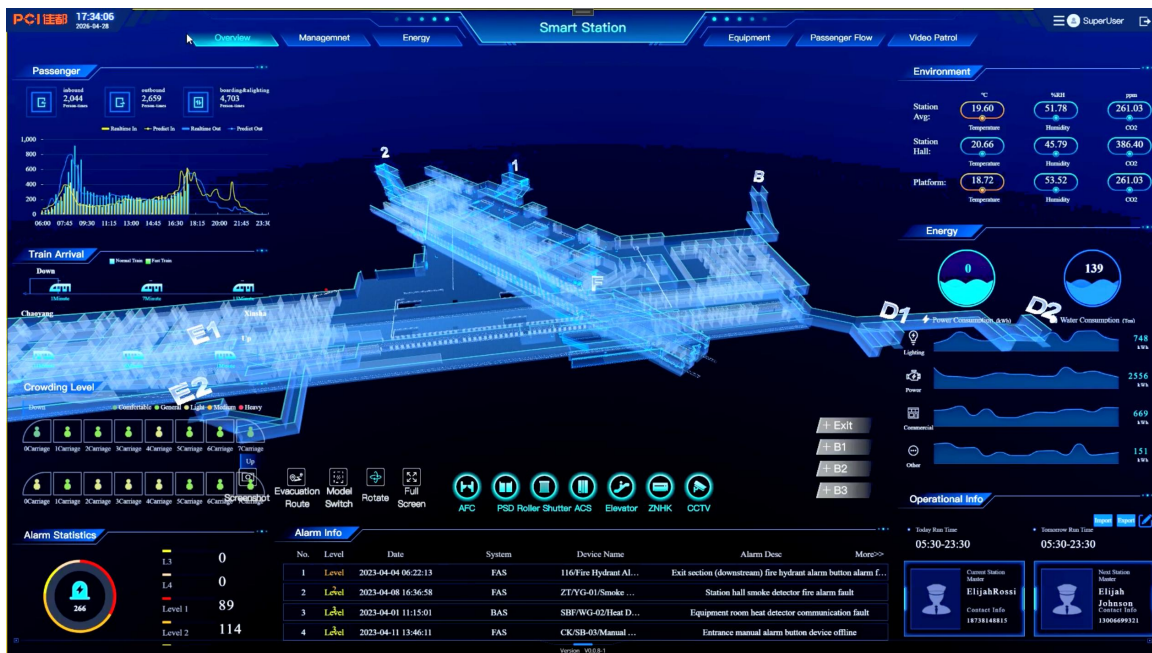
5.1.2.7 Alarm Manager

At any time, the control platform software can select equipment diagrams via mouse or keyboard to browse the status of monitored equipment.

There are two forms of status overview: alarm logs (list) and event logs (list).

Event/alarm logs are used to record status changes, alarms, controls, configurations, and modifications of all equipment by time.

Provides dynamic screens displaying all monitored equipment.



5.1.3 One-Click Station Opening/Closing

5.1.3.1 One-Click Station Opening

Provides the following functions, including:

Morning station opening requires, based on the station opening execution steps of operation personnel before operation, to solidify the linkage of various systems during the station opening process into automated, rationalized, and procedural plans. Starting morning station opening sends control commands to each system. After receiving the "station opening" command, each system turns on the corresponding equipment and feeds back the equipment operating status in real time to the Smart Station subsystem backend. Station personnel at each station complete station opening work in a timely manner based on equipment operating status, effectively reducing the workload of metro operation personnel and improving operation work quality and efficiency.

One-click station opening linkage and functional requirements:

No.	Discipline	System Linkage Requirement	Function Description
1	BAS	Environmental Control Mode	Link to execute morning station opening mode

		Control	
2		Escalator/Elevator Operation Mode Control	Link BAS to control escalator/elevator startup
		Vertical Elevator Operation Mode Control	Link BAS to control vertical elevator unlock
3		Rolling Shutter Control	Link rolling shutter to open
4	PA	Station Opening Broadcast	Link PA to broadcast station opening information
5	PIS	Station Opening PIS Display	Link PIS to display station opening information
6	PSD	PSD Door Open/Close Self-Test	Link PSD to perform 3 door open/close tests
7	AFC	AFC Mode Control	Automatically check and confirm AFC equipment operation mode
8	Smart Lighting	Smart Lighting Mode	Switch smart lighting mode
9	CCTV	CCTV Feed	Display video feeds of equipment areas requiring confirmation
10		Camera Position Information	Display camera position information for required video feeds

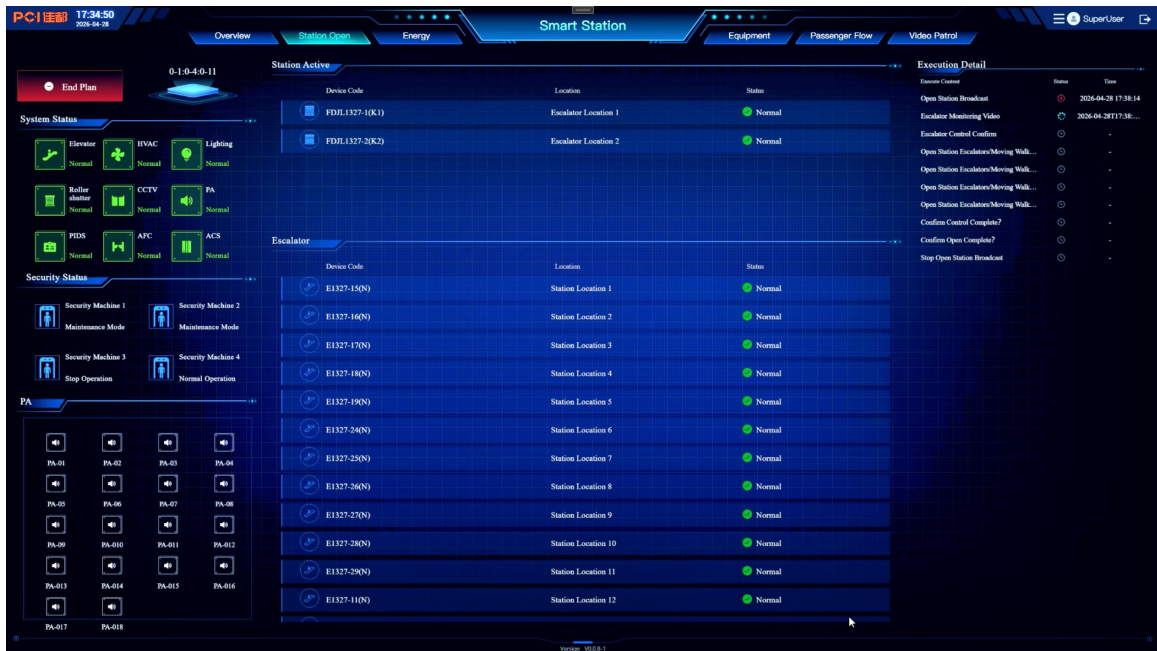
5.1.3.2 One-Click Station Closing

Provides the following functions, including:

Evening station closing requires, based on the station opening execution steps of operation personnel before operation, to solidify the linkage of various systems during the station closing process into automated, rationalized, and procedural plans. Starting intelligent station closing sends control commands to each system. After receiving the "station closing" command, each system turns off the corresponding equipment and feeds back the equipment operating status in real time to the Smart Station subsystem backend. Station personnel at each station complete station closing work in a timely manner based on equipment operating status, effectively reducing the workload of metro operation personnel and improving operation work quality and efficiency. Intelligent station closing system linkage and functional requirements.

Evening station closing system linkage and functional requirements. Specific station closing functions support adjustment according to actual operation business needs:

No.	Discipline	System Requirement	Linkage	Function Description
1	BAS	Environmental Control Mode Control		Link to execute evening station closing mode
2		Escalator/Elevator Operation Mode Control		Link BAS to control escalator/elevator shutdown and operation mode
3		Vertical Elevator Operation Control		Link BAS to control vertical elevator lock
4		Rolling Shutter Control		Link rolling shutter to close
5	PA	Station Closing Broadcast		Link PA to broadcast station closing information
6	PIS	Station Closing PIS Display		Link PIS to display station closing information
7	AFC	AFC Mode Control		Automatically check and confirm AFC equipment operation mode
8	Smart Lighting	Smart Lighting Mode		Switch smart lighting mode
9	CCTV	CCTV Feed		Display video feeds of equipment areas requiring confirmation
10		Camera Position Information		Display camera position information for required video feeds



5.1.3.3 Station Opening/Closing Records

Records station opening/closing time and station opening/closing process records in real time, facilitating subsequent traceability.

5.1.4 Video Inspection Patrol

5.1.4.1 Video Inspection Patrol

Provides automated inspection functionality. Supports completing video inspection of the station according to specified video inspection routes, providing route planning, one-click inspection, and inspection settings functions.

1. Route Planning

The user manually selects a pre-configured video inspection route and starts the inspection task. The system retrieves corresponding surveillance feeds in the configured camera order (each camera feed's dwell time is executed according to the duration set in the inspection route). The feed displays equipment in front of the camera, facilitating inspection personnel in observing the current equipment status. If inspection personnel discover abnormal equipment conditions, they can pause the inspection task and record the abnormality. Inspection personnel can resume the paused inspection task at any time to complete a full inspection.

2. One-Click Inspection

After starting one-click station inspection, the system should simulate operation and maintenance personnel automatically walking in the 3D scene, retrieving camera feeds within the route range and displaying them on the interface. The selected inspection route should automatically form a walking path in the 3D scene. Achieve the function of automatic roaming in the 3D scene according to the specified route. Support linking cameras to display real-time camera feed information.



3. Inspection Settings

The system supports setting some parameters during the inspection process, such as inspection node dwell time and whether to loop inspection. Supports whether to start loading the 3D scene for video station inspection. Supports inspection node video feed playback duration. Supports whether to loop station inspection according to the inspection route, while providing the function to set the number of loops.

5.1.5 Equipment Inspection Patrol

5.1.5.1 Equipment Station Inspection Function

The user manually selects a pre-configured equipment inspection route and starts the inspection task. The system retrieves real-time panel data of corresponding equipment in the confinement order, facilitating inspection personnel in observing the current equipment status. If inspection personnel discover abnormal equipment conditions, they can pause the inspection task and record the abnormality. Inspection personnel can resume the paused inspection task at any time to complete a full inspection.

Supports providing abnormal equipment events or faults monitored by the integrated supervisory control alarm module.

5.1.6 Electronic Emergency Response Plans

5.1.6.1 Electronic Emergency Plan Compilation

During daily operation, the system supports pre-arranging and managing emergency response plans for various types of unexpected events (such as fire, flooding, passenger assistance requests, equipment faults, etc.). For different event types, the system can differentially organize and configure key response steps based on the user's organizational structure and position roles. Through this standardized pre-arrangement, complex emergency procedures are transformed into clear, executable task lists, ensuring that personnel in different positions can clarify their own responsibilities when facing unexpected situations.

5.1.6.2 Emergency Event Response

When an emergency event actually occurs, staff can rely on the system to quickly launch the corresponding emergency response plan. The system will guide response personnel through item-by-item confirmation and operation according to pre-arranged content, ensuring that no key information or steps are omitted during the response process. At the same time, the interface intuitively displays the event name, response process, and relevant personnel involved. The bottom of the interface also integrates commonly used emergency unit contact information (such as passenger emergency intercom phones, police phones, medical emergency phones, operation control center phones, etc.), facilitating command personnel in quickly obtaining emergency unit contact information under emergency conditions.

5.1.6.3 Post-Event Review

After emergency response is completed, the system automatically records and retains the entire event handling process. Management personnel can view detailed response trajectories, task confirmation time nodes, and the response status of each role through the system. This forms visual traceability of emergency response.

5.2 Intelligent Analysis System

5.2.1 Platform Screen Door Intelligent O&M

5.2.1.1 System Homepage

The Platform Screen Door Intelligent O&M system homepage includes line-level and station-level two-tier visualization interfaces. The line overview intuitively displays the distribution of all stations along the line using a line diagram, supporting zooming and dragging. Stations identify alarm and warning information through red and orange flashing indicators and display the number of events. Below, an alarm list scrolls, with configurable alarm levels. The page is equipped with customizable widgets that visually display alarm statistics, trends, fault TOP rankings, and O&M efficiency indicators. Clicking a station seamlessly jumps to the station interface, centrally displaying the operating conditions of various door types such as sliding doors and emergency doors, while synchronously presenting interface and button status such as signal linkage and emergency unlock, achieving integrated O&M management from line-wide macro monitoring to individual station equipment detail viewing.





5.2.1.2 Key Component Dashboard

The Key Component Dashboard mainly targets key operating components inside the sliding door header machine compartment, focusing on four core components: DCU door controller, drive motor, electromagnetic lock, and door panel. It intuitively presents the operating status of equipment components that cannot be seen during routine O&M patrols, as well as their electrical parameter information. Each module of the dashboard implements targeted data monitoring and analysis: the DCU door controller module monitors working status, input/output signals, and fault codes in real time, combines historical data to analyze operating trends and automatically calculates reliability scores, pushing performance degradation warnings when scores fall below thresholds; the drive motor module monitors key parameters such as start/operating current, voltage, and temperature, compares historical averages to analyze load changes, and combines operating hours and start/stop frequency to predict potential faults such as stalling and motor wear; the electromagnetic lock module monitors open/close status and records action logs, analyzes hazards such as abnormal lock lifting, evaluates A/B/C three-level safety grades, and immediately triggers safety warnings when hazards exceed standards; the door panel module precisely monitors indicators such as operating speed, displacement precision, and door resistance changes, judges problems such as guide rail wear and pulley jamming through data fluctuations, and combines maintenance records to

evaluate mechanical performance, recommending targeted maintenance measures such as guide rail cleaning and lubrication and pulley replacement when scores are too low.



5.2.1.3 Power System Monitoring

Battery/power system monitoring mainly obtains key data such as board and module status, indicator light displays, and meter readings of power cabinets and battery packs in equipment rooms through data interfaces, and generates a dedicated power system operation dashboard to fully restore on-site equipment operating status. It also supports viewing real-time and historical playback screens of the power operation dashboard, and is equipped with a one-click intelligent inspection function that can automatically generate inspection reports based on monitoring points. This module can replace the manual inspection method of running from station to station and equipment room to equipment room, and can automatically complete the generation and archiving of inspection reports, greatly improving O&M inspection efficiency.



5.2.1.4 Action Record Analysis

The Platform Screen Door Intelligent O&M system provides an action record and intelligent analysis interface. The system acquires digital data such as relays and interface commands during platform screen door opening/closing in real time, as well as key analog data such as motor current, door panel movement displacement, and speed curves, thereby building a complete operating status database. Such data includes not only the logical timing of commands but also dynamic parameters during door panel operation, such as motor current change trends and door panel movement displacement and speed curves. Through comprehensive analysis of these data, the system can fully grasp the operating status of platform screen doors, identify potential abnormal conditions, and provide a scientific basis for fault diagnosis and predictive maintenance.



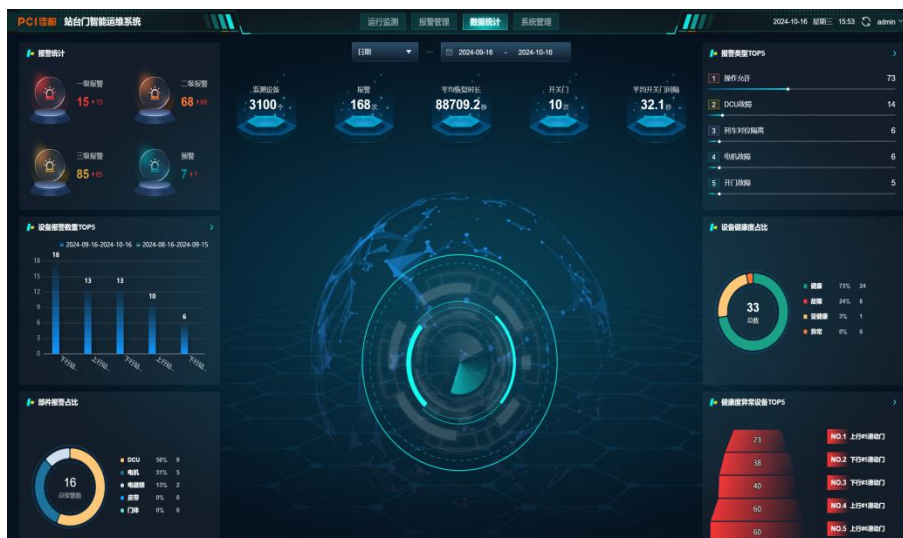
In terms of action logic timing inspection, the system can intelligently identify whether the platform screen door opening/closing action linkage is normal and whether there are problems such as command delay, loss, or erroneous execution. For example, after the platform screen door system receives a door opening/closing command from the signal system, the system checks in real time whether the DCU, motor, electromagnetic lock, belt, door panel, etc. respond and execute corresponding actions within the specified time. If abnormal command execution is found, the system immediately records relevant operating data and locates the internal root cause of the command abnormality through algorithms, such as platform screen door controller failure, abnormal motor startup, or transmission component jamming. Through rapid and precise localization of such problems, the system can help maintenance personnel quickly find the root cause of faults, greatly reducing fault troubleshooting time and avoiding operation interruptions or other safety problems caused by platform screen door self-faults.

In terms of analog data analysis, the system can identify the operating trends of each individual sliding door through real-time monitoring of motor current, door panel displacement, and speed curves. For example, when abnormal fluctuations appear in the motor current curve, the system can determine whether the motor has problems such as overload or unstable operation; when door panel displacement and speed curves deviate from normal ranges, the system can detect phenomena such as door panel jamming or

abnormal operating speed. Through analysis of these trends, the system can proactively discover potential hazards such as abnormal door resistance, timely trigger warnings to remind maintenance personnel to intervene and dispose, thereby effectively avoiding fault occurrence and ensuring normal operation of platform screen doors and passenger safety. This predictive maintenance model not only reduces the probability of fault occurrence but also extends equipment service life and reduces comprehensive maintenance costs.

5.2.1.5 Data Statistics Analysis

The data statistics analysis module of the Platform Screen Door Intelligent O&M system can present the alarm situation of the entire line at different levels, simultaneously summarizing the total number of monitored equipment, alarm frequency, average fault recovery time, and core indicators related to door opening/closing, to quickly grasp overall operating trends. At the same time, through charts such as alarm type rankings, equipment alarm quantity rankings, and component alarm proportions, it can locate high-frequency fault types and at-risk components; combined with equipment health proportion and health-abnormal equipment rankings, it can precisely assess equipment health levels and identify high-risk equipment.



5.2.2 AFC Intelligent O&M

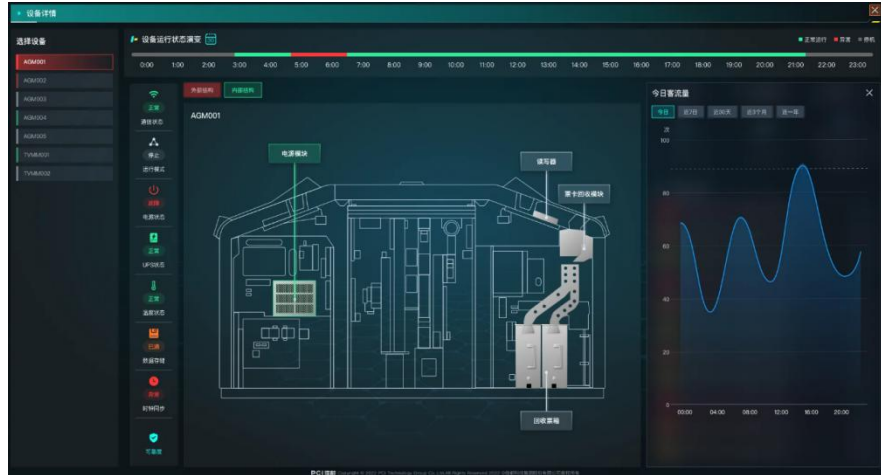
5.2.2.1 System Homepage

The AFC Intelligent O&M station monitoring homepage relies on a visualization network topology interface to graphically display the connection status of station terminal equipment such as turnstiles, TVMs, and servers, as well as network links. It supports station-wide or equipment room partitioned viewing. The topology distinguishes equipment performance and alarm levels through colors; mouse hovering allows viewing key equipment information, and it supports custom topology layout and indicator display, achieving centralized and intuitive monitoring of station AFC equipment networks.



5.2.2.2 Equipment Module-Level Monitoring

The equipment module-level monitoring function of the AFC Intelligent O&M system can perform refined component monitoring on station terminal equipment such as turnstiles and TVMs. The interface displays the internal structure wireframe of the equipment, intuitively presenting components such as power modules, card reader/writers, ticket card recycling modules, and recycled ticket boxes. The left side centrally displays real-time status of each module such as communication, power, and temperature; the top timeline records equipment operating status changes; the right side synchronously displays passenger flow curves. This achieves visualization of internal component status of individual equipment, supporting module-level fault localization and equipment operation analysis.



5.2.2.3 Intelligent Statistics Analysis and Decision

The AFC Intelligent O&M statistics analysis and decision module includes equipment reliability statistics analysis and preventive maintenance decision support functions. The system dynamically monitors equipment integrity rate and fault frequency indicators at a minimum acquisition granularity of 15 minutes, marks persistently abnormal equipment, generates reliability reports and heatmaps, and intuitively displays the spatiotemporal distribution of faults. It also dynamically calculates MTBF and sets differentiated thresholds, combines equipment usage rates to build a maintenance priority matrix, identifies high-risk equipment, and pushes preventive maintenance recommendations, driving O&M to shift from passive emergency repair to proactive prevention.



The module also has passenger flow-equipment balance optimization and report analysis capabilities. The system counts turnstile door opening/closing frequency, outputs equipment usage reports, supports custom equipment grouping, provides turnstile start/stop strategy recommendations, and balances equipment loads to reduce uneven wear. It can automatically generate daily/monthly/quarterly/annual O&M reports, output statistical conclusions and auxiliary decision recommendations, supporting O&M personnel in coordinating equipment O&M management.

5.2.3 Communications Intelligent O&M

5.2.3.1 System Homepage

The Communications Intelligent O&M line overview homepage integrates multi-dimensional O&M data dashboards, aggregating core modules such as station operating status, various alarm statistics, alarm trends, TOP fault rankings, alarm recovery time, and real-time alarms. The page visually presents the overall line O&M situation. Abnormal stations are highlighted with red flashing to indicate emergency and severe

alarms, allowing quick viewing of station alarm information. The homepage displays unrecovered alarms in real time, sorted in reverse chronological order, supporting paginated viewing and alarm detail retrieval. Platform screen door alarms can directly reach the equipment monitoring interface, and alarm content supports rule customization, achieving centralized monitoring and rapid disposal of faults across the entire line.



5.2.3.2 Equipment Monitoring Function

The Communications Intelligent O&M system achieves integrated intelligent monitoring of metro multi-discipline communications subsystems. It supports cabinet visualization simulation monitoring, intuitively displaying the operating conditions of switches, power supplies, and various board equipment inside cabinets. When equipment is abnormal, red flashing alarms occur, and real-time equipment parameters, environmental status, and alarm details can be viewed. The system relies on network topology to fully present all network elements and link connection architectures across the line, with fault nodes prominently indicated, supporting network element detail query and historical data traceability. It covers multiple subsystems such as video surveillance, power supply, train-ground wireless, dedicated transmission, and passenger information, aggregating equipment status and alarm events to achieve full-domain status perception

of communications equipment, assisting O&M personnel in quickly identifying and locating fault hazards, and improving communications system O&M disposal efficiency.



5.2.3.3 End-to-End Intelligent Analysis Function

The end-to-end analysis function can display the complete equipment business topology diagram of a station, intuitively presenting all link nodes from front-end business equipment to the backend platform. When any equipment in the link generates an alarm, the node is highlighted in red. It supports alarm normalization analysis, which can aggregate and organize associated alarm information within the link. O&M personnel can quickly locate the link position of the fault through the topology, clarify fault propagation relationships, assist in determining the root cause of faults, reduce ineffective troubleshooting, and achieve fault traceability and problem analysis for the full communications business link.



5.2.4 Integrated Supervisory Control System

5.2.4.1 Host Equipment Performance Detection

Addressing the problem that the Integrated Supervisory Control System lacks monitoring means for underlying infrastructure such as servers, network switches, and data forwarding hosts that support the stable operation of the entire system, the Integrated Supervisory Control Maintenance Management System strengthens the monitoring of performance indicators for core underlying equipment of the ISCS, including three types of equipment: servers/FEP hosts, core switches, and dispatcher workstations. It collects full-dimensional indicators of hardware resources, network links, and program operation in real time, proactively identifying system operation hazards and ensuring the continuous, stable, and reliable operation of the ISCS platform.



5.2.4.2 Equipment Status Assessment

The equipment status assessment submodule targets various electromechanical equipment managed by the ISCS. Relying on equipment start/stop sequences, analog and digital historical data, operating hours, and maintenance work orders, it builds a multi-dimensional health analysis model to quantify equipment operating characteristics and identify performance degradation and component aging hazards. The built-in statistics engine automatically aggregates multi-cycle operation data and generates trend reports. It can compare historical load changes under different operation scenarios. When abnormal fluctuations in operating hours or start/stop frequency occur, it predicts hidden fault risks and provides early warnings, ensuring stable operation of equipment such as environmental control, water supply and drainage, escalators/elevators, and platform screen doors, and avoiding disruption to operations caused by sudden faults.



5.2.5 Escalator and Elevator Intelligent O&M

5.2.5.1 Equipment Monitoring Function

The Escalator and Elevator Intelligent O&M real-time monitoring system is mainly oriented to application scenarios with complex on-site environments, a large number of equipment, and long traditional manual inspection time. It can accurately and timely feedback on-site operating status, effectively supporting remote fault diagnosis and troubleshooting. The system continuously monitors the collected values of each equipment component and, based on a dynamic threshold model, achieves real-time comparison between monitoring parameters and alarm thresholds. When equipment data is detected to deviate from the system's preset safety baseline, the system initiates the corresponding graded response mechanism based on the three-level risk warning system (normal, minor, severe).



5.2.5.2 Intelligent Analysis and Diagnosis Function

The intelligent analysis and diagnosis function of Escalator and Elevator Intelligent O&M aggregates conventional ISCS points, medium-low frequency electrical parameters/temperature/humidity, and vibration-noise high-frequency acquisition data. It sequentially completes equipment condition calibration, data cleaning, frequency-domain separation and envelope extraction, frequency-domain transformation and windowing, and then performs feature matching with fault models. The system calculates fault probability at the whole-machine, module, and component levels. When fault probability exceeds the set threshold, it automatically triggers a warning, prompting O&M personnel to carry out intervention and disposal in a timely manner, achieving early identification and prediction of escalator/elevator faults.



5.2.5.3 Trend Traceability Function

The Escalator and Elevator Intelligent O&M system can view real-time and historical analog curve trends of collected measurement points; and can separately add warning and alarm baselines for each curve of each equipment, with the baselines also adaptively adjusted through algorithm models. Maintenance personnel can view the analog curve trend distribution of each component before and after warning and alarm abnormal time points.



5.2.5.4 Spectrum Analysis Function

The Escalator and Elevator Intelligent O&M system can obtain clear and explicit spectrum data through the spectrum analysis function and assist experts in further manual diagnosis. The system applies signal transformation, time-domain analysis, frequency-domain analysis, envelope demodulation, frequency component extraction, noise reduction, phase calculation, and other analysis techniques to the collected vibration waveforms. It displays the energy and waveform changes of vibration acceleration, velocity, and displacement signals in the time domain and frequency domain, as well as the phase differences between different measurement points.

The system can automatically add multiple prompt marker lines related to equipment fault diagnosis, such as commonly used 1x frequency, 2x frequency, outer race or inner race fault frequency bands, and other information. It quickly locates energy anomalies for

convenient fault finding. This module will support customers in custom-adding marker lines, and the software automatically adds relevant harmonic marker lines and sideband marker lines, while assisting in calculating harmonic and sideband energy intervals.



VI. Proven Implementation Cases

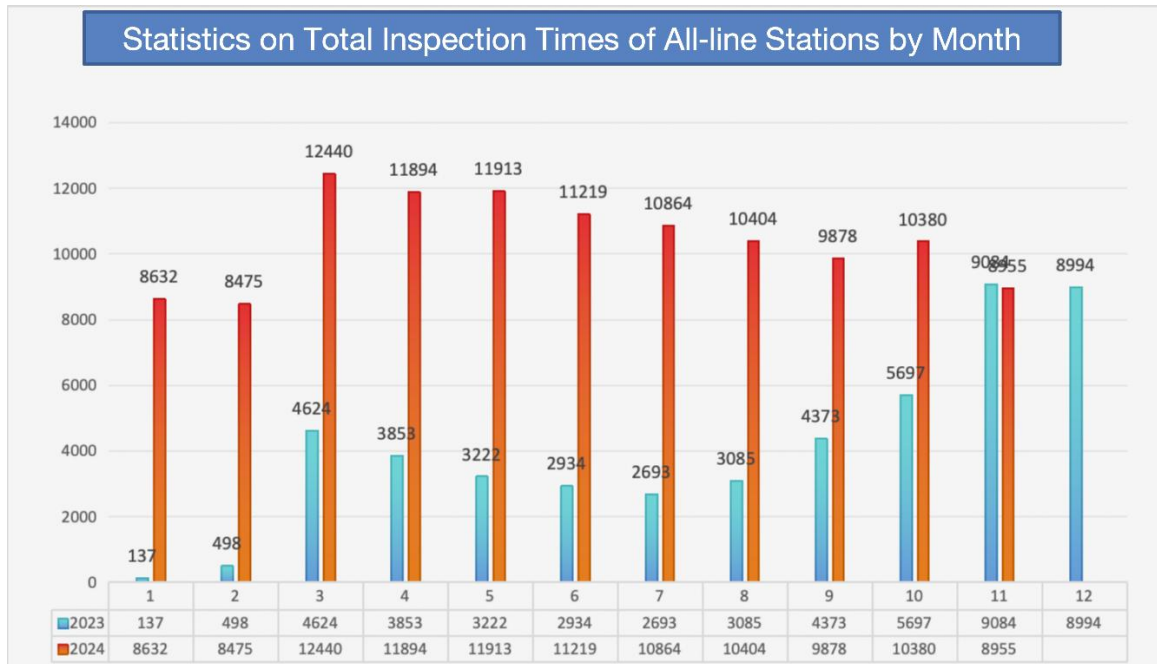
The solution has been implemented at scale on multiple metro lines in China, with mature engineering implementation experience and replicable delivery capabilities.

Case 1: Guangzhou Metro Lines 18, 22, and Tianhe Smart City Station on Line 21 have implemented comprehensive applications including panoramic control, holographic perception, data analysis, intelligent customer service, intelligent ticket inspection and sales, intelligent security inspection, intelligent safety and security, one-click station opening/closing, 3D assisted monitoring, video station inspection, energy management, O&M management and alarms, and mobile station operations. Previously, manual station inspection took about 1 hour, while video station inspection takes only 10 minutes; automatic equipment warnings greatly reduce on-site O&M workload, making station operation management more lightweight and emergency response more efficient.



Interface of the Deployed Smart Station Operation Control Platform

Case 2: Changsha Metro Line 6 is China's first line with smart stations implemented across the entire line, covering functions such as panoramic control, intelligent station opening/closing, intelligent inspection, intelligent customer service, emergency command, operation indicator statistics, smart energy saving, intelligent flood prevention, intelligent security inspection, passenger guidance, and line-level control. After going live, it has significantly improved quality, reduced costs, and increased efficiency in energy saving, security inspection, customer service, operation, and O&M. In 2024, the total number of video inspections at all stations along the line reached over 110,000. On average, each station conducted 9.8 video inspections per day, with an average duration of 5.1 minutes per inspection. The average operation time for one-click station opening/closing across all stations was 6.1 minutes for morning opening and 6.2 minutes for evening closing.



Statistics of Total Inspection Counts at All Stations Along Changsha Line 6 by
Month

In addition, PCI has implemented applications such as one-click station opening/closing, comprehensive dashboard, video inspection, panoramic station inspection, one-click self-inspection, free-form inspection, equipment room inspection, remote electromechanical inspection, smart passenger flow, emergency management, flood situation analysis, escalator emergency control, and automated data reporting on Chengdu Metro Lines 17, 18, and 19. Projects such as Dalian Xi'an Road Station and Ningbo Metro Line 7 have also been implemented.

The above projects cover both new line construction and existing line renovation scenarios, spanning different scales from mega-network cities to regional central cities. This verifies the adaptability and replicability of the solution under different construction conditions and operation requirements and can provide mature implementation paths and risk management experience for subsequent projects.