

TRI 吉泰智能

Leader in AI-Based Intelligent Operation and Maintenance for High-Risk High-Altitude Energy Operations

Focusing on providing full-stack, integrated (monitoring, diagnosis, inspection, patrol, safety) lifecycle intelligent O&M products and services for large-scale energy facility enterprises, with advanced self-developed wall-climbing inspection robots for high-altitude operations, AI-driven defect data/models/algorithms, and an intelligent O&M platform software based on digital twins.

Zhejiang Tri-tech. Co., Ltd.

Beijing Tri-tech. Co., Ltd.

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Typical Cases



Preface

China has a large number of key energy facilities, which are the lifeline of the national economy and are of great significance for ensuring national security and social stability.

China is the world's largest electricity producer. According to data from the National Bureau of Statistics, China's electricity generation reached 8.26 trillion kilowatt-hours in 2020, supported by massive power generation facilities, including thermal power plants, hydropower plants, wind farms, photovoltaic power stations, and nuclear power plants.

As of the end of 2021, there were approximately 5,000 thermal power plants in China, with more than 20,000 operational units. Additionally, there were over 10,000 desulfurization towers;

Currently, there are over 3,500 wind farms in China, with a total of more than 200,000 installed units.

In the field of hydropower, there are more than 23,800 dams over 30 meters high across the country.

At the same time, China is the world's largest importer of crude oil and natural gas. According to data from the National Energy Administration, China imported 590 million tons of crude oil and 1.3 trillion cubic meters of natural gas in 2020. There are more than 60,000 large storage tanks as major facilities. Additionally, **China has the world's largest nuclear power plant construction scale.** According to the National Energy Administration, as of 2020, there were 49 operational nuclear power units with a total installed capacity of 51.7 gigawatts, and 16 nuclear power plants under construction or planned, with a total installed capacity of 18.1 gigawatts.

The operation and maintenance of large key energy facilities have the following characteristics: 1) They are critical infrastructure for the national economy; 2) They are massive in size, height, and area; 3) O&M work requires complex high-altitude operations; 4) Equipment requires long lifecycle maintenance, lasting 25-30 years; 5) Any safety accidents have significant social and ecological impacts.

Currently, traditional manual O&M modes face core issues such as low coverage, low accuracy, low efficiency, low safety, and non-real-time detection data.

The energy industry is currently vigorously promoting the demonstration phase of intelligent and digital power plants. Intelligent digital power plants are part of the power industry's gradual implementation of industrial automation (Industry 4.0), advanced information technology (Internet+), and the trend of integrating informatization and industrialization. This involves adding an "intelligent" core for operation, maintenance, management, and decision-making to power stations. Among these, the use of intelligent robots for inspection, maintenance, and examination is a key aspect of smart energy.

The future will see a rapid growth period for the intelligent O&M market of large-scale energy facilities, reaching a trillion-yuan scale.

About TRI-TECH

Zhejiang Tri-tech. Co., Ltd., established in 2023, fully owns Beijing Tri-teh. Co., Ltd. (founded in 2015). The company specializes in providing full-stack, lifecycle intelligent O&M services for large-scale energy facility enterprises, integrating "monitoring, diagnosis, inspection, patrol, and safety" with advanced self-developed wall-climbing robots for high-altitude operations, digital twin technology, intelligent O&M software, and a new generation of inspection services. The company's products and services cover thermal power, wind power, nuclear power, power grids, coal, petrochemicals, and steel.

The company is a leading enterprise in the field of intelligent O&M for high-altitude operations on large-scale energy facilities in China, with product technology comparable to that of GE in the United States. The company possesses multiple world-leading core hardware technologies for wall-climbing robots, such as adsorption technology for different material surfaces (metal and non-metal), flexible structure adaptive control technology for various wall curvatures, integrated positioning analysis technology for complex 3D spaces, multi-robot distributed control and collaboration technology, and multi-disciplinary robot simulation.

In terms of core software technology, the company drives "defect data, algorithms, and models" with artificial intelligence, independently developing an intelligent O&M PaaS platform suitable for the energy sector. This platform includes self-developed digital twin core technology and intelligent fault diagnosis technology for the energy sector.

The company currently holds 76 patents and 46 software copyrights. It is a Beijing "Specialized and New" enterprise, a Beijing Intellectual Property Pilot Unit, and an International Creative Management Demonstration Base. The company formulated the first domestic robot standard for thermal power boilers, "General Technical Standard for Boiler Wall-Climbing Robots," issued by the National Energy Administration, and jointly compiled by the company, Tsinghua University, and Huaneng Group's Xi'an Thermal Power Research Institute. It also formulated the "General Technical Standard for Coal Conveyor Gallery Inspection Robots in Thermal Power Plants" and participated in the formulation of two robot standards: "Evaluation Method for Accelerated Life Test Performance Degradation of Industrial Robots" and "Evaluation Index and Test Method for Dynamic Stability of Industrial Robots."

The company is a qualified supplier to groups such as State Grid, Southern Grid, CNNC, CGN, SPIC, China Energy Group, Huaneng, Huadian, Datang, and the Three Gorges Corporation. In the field of intelligent O&M for thermal power boilers, the company has over 200 demonstration cases, ranking first in the industry. Its independently developed TRI thermal power boiler water wall inspection robot has been recognized by the China Electricity Council as reaching international leading levels, and the TRI thermal power boiler four-pipe health analysis system has been recognized as reaching domestic leading levels. These products are widely used in major thermal power enterprises in China, such as Guoneng Taishan, Datang Wangtan, Lubei, Guoneng Jianbi, Quanzhou, Huaneng Laiwu, Changxing, and Zheneng Fengtai.

In the field of intelligent O&M for wind power, Tri-tech. has completed the first domestic full-scenario intelligent O&M solution for wind power. Its independently developed TRI wind power tower cleaning and inspection robot, wind turbine nacelle inspection robot, and blade inspection robot have been successfully deployed in multiple wind power enterprises, such as Guoneng Jishanliang, SPIC Qianzhan, Datang Chifeng, Huaneng Jingbian, Guangdong Electric Power Yangjiang, and Shibeishan wind farms.

Tri-tech. maintains long-term strategic partnerships with universities such as Tsinghua University, Wuhan University, North China Electric Power University, Beijing University of Chemical Technology, and Beijing University of Posts and Telecommunications.

01

Intelligent Operation and Maintenance of Thermal Power Plants

Boiler Intelligent Operation and Maintenance Solutions

- Boiler Four-Pipe Health Analysis System
- Boiler Water Wall Inspection Robot System
- Boiler Macro Inspection Drone System
- Metal Intelligent Handheld Positioning Detector
- Telescopic Pipeline Inspection Robot System
- Small Magnetic Adsorption Pipeline Inspection Robot System
- Small Magnetic Adsorption Metal Inspection Robot System

Personnel Safety Management System

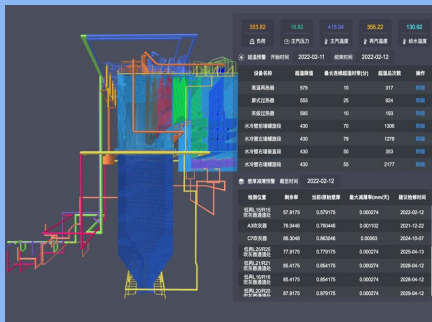
- Dual Pre-Control System
- High-Risk Work Personnel Safety Management System

Intelligent Inspection System

- Coal Conveyor Gallery Inspection Robot
- Plant Joint Inspection

Overall Architecture of Boiler Intelligent Operation and Maintenance

Boiler Health



Boiler Four-Pipe Health Analysis System

Intelligent Robots



Boiler Wall-Climbing Robot System

Intelligent Hardware



Other Boiler Intelligent Operation and Maintenance Hardware Systems

Ledger Management

Fault Knowledge Base

Fault Diagnosis

Three-Dimensional Visualization

Maintenance Guidance

Thickness Data Integration

Drum Cleaning

High-Pressure Water Cleaning

Defect Identification

Ultrasonic Thickness Measurement

Non-Destructive Testing (NDT)

Bulging Detection

Drone

Intelligent Handheld Detection

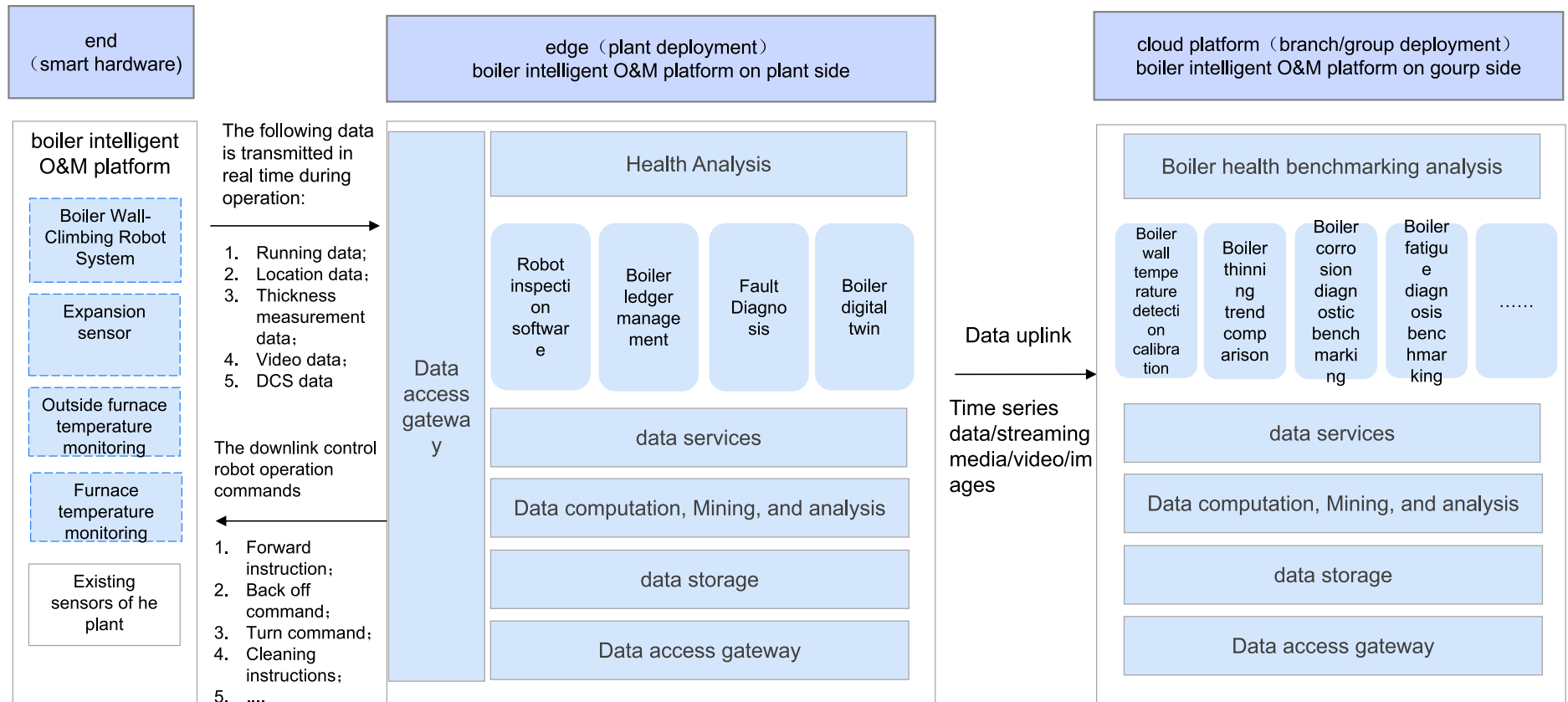
Large Pipe Inspection

Small Pipe Inspection

Small Metal Detecting Robot

Boiler Four-Pipe Health Analysis System

Cloud-Edge-End Structure

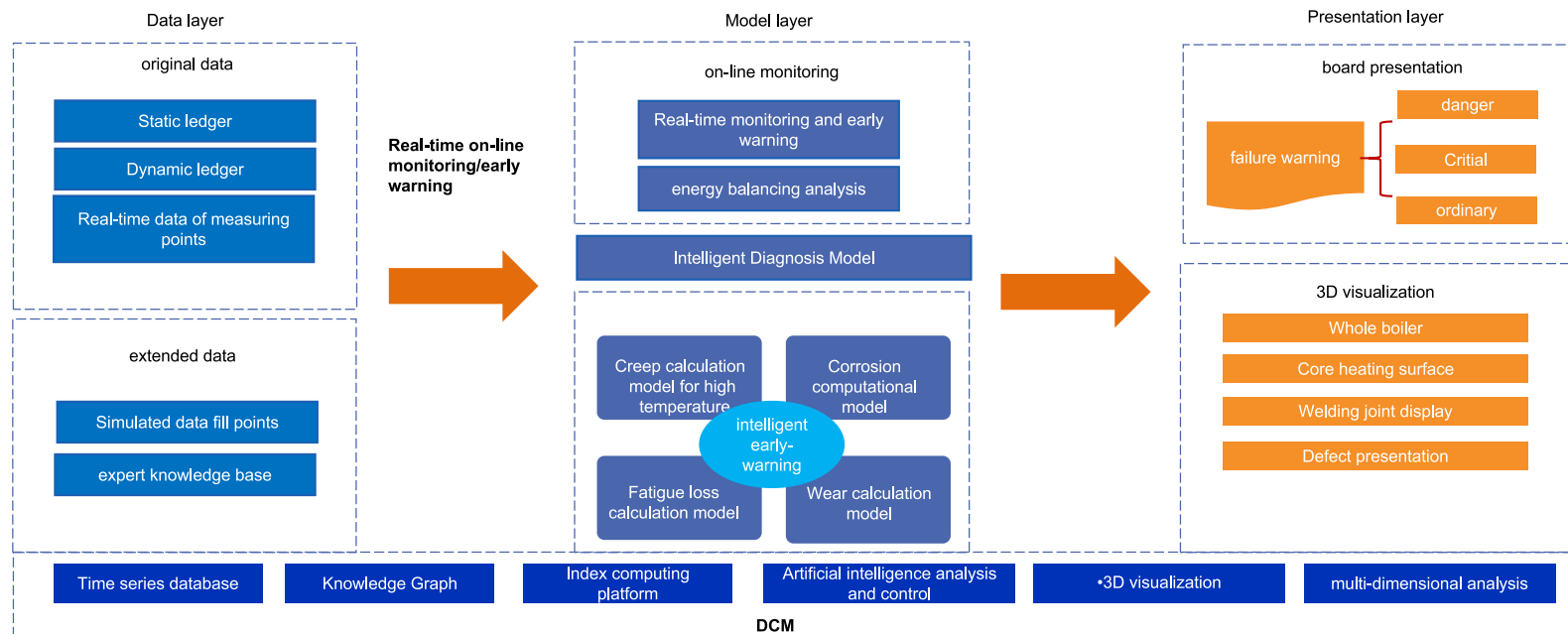


Boiler Four-Pipe Health Analysis System

Current Industry Situation

1. Few sensors early on: There was a 10-fold difference in the number of boiler measurement points between new and old units, unable to comprehensively reflect the operating condition of the boiler;
2. Traditional monitoring and warning methods need improvement: There are two problems with using the SIS for boiler monitoring and warning - one is that access is inconvenient requiring a jump server, and two is the lack of long-period historical data statistics and analysis, unable to effectively assist specialists in statistics and analysis;
3. Lack of effective equipment ledger management: The boiler equipment maintenance ledger is currently manually maintained, scattered across different specialists' computers, lacking centralized management;
4. Lack of intelligent tube rupture diagnostic model: There is a lack of effective means for detecting boiler tube rupture defects, unable to discover problems in a timely manner;
5. Current boiler monitoring is mainly in the form of configurations and charts, unable to visually display the overall effect.

Product Introduction



Boiler Four-Pipe Health Analysis System

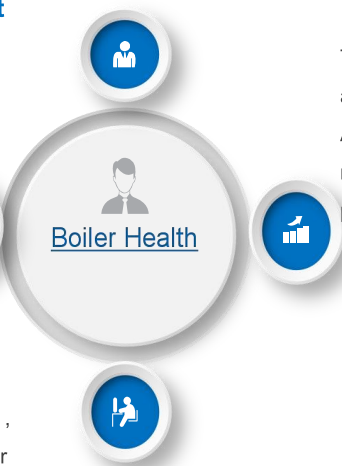
Product Value

Orderly Ledger Management

Changing from previously manually scattered maintenance to centralized online maintenance, realizing centralized management of boiler equipment ledger information.

Tube Rupture Warning and Diagnosis

Provides highly accurate, quantitative fault prediction for boiler four-pipe health, with an accuracy rate of over 80%.



Reduced Unplanned Outages

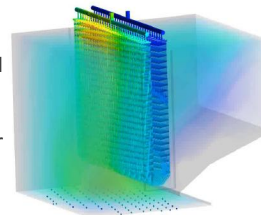
Provides accurate maintenance plans and solutions. Under normal circumstances, it can reduce unplanned outages caused by boiler tube leakage by more than 50%.

3D Visualized Interactive Interface

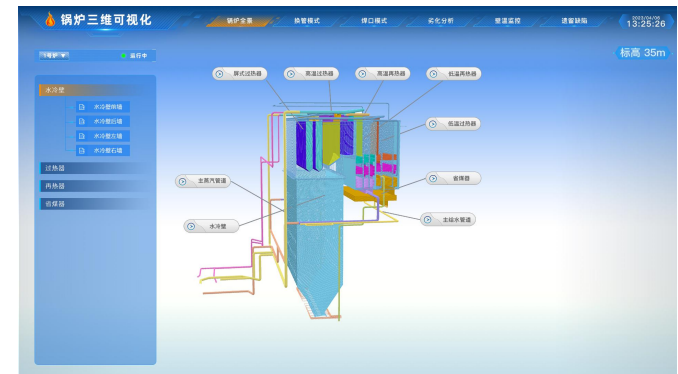
The main equipment achieves 3D visualization and dynamic operation simulation. Abnormalities are accurately located on the 3D model, realizing a visual revolution in power plant monitoring.

Efficiency Improvement

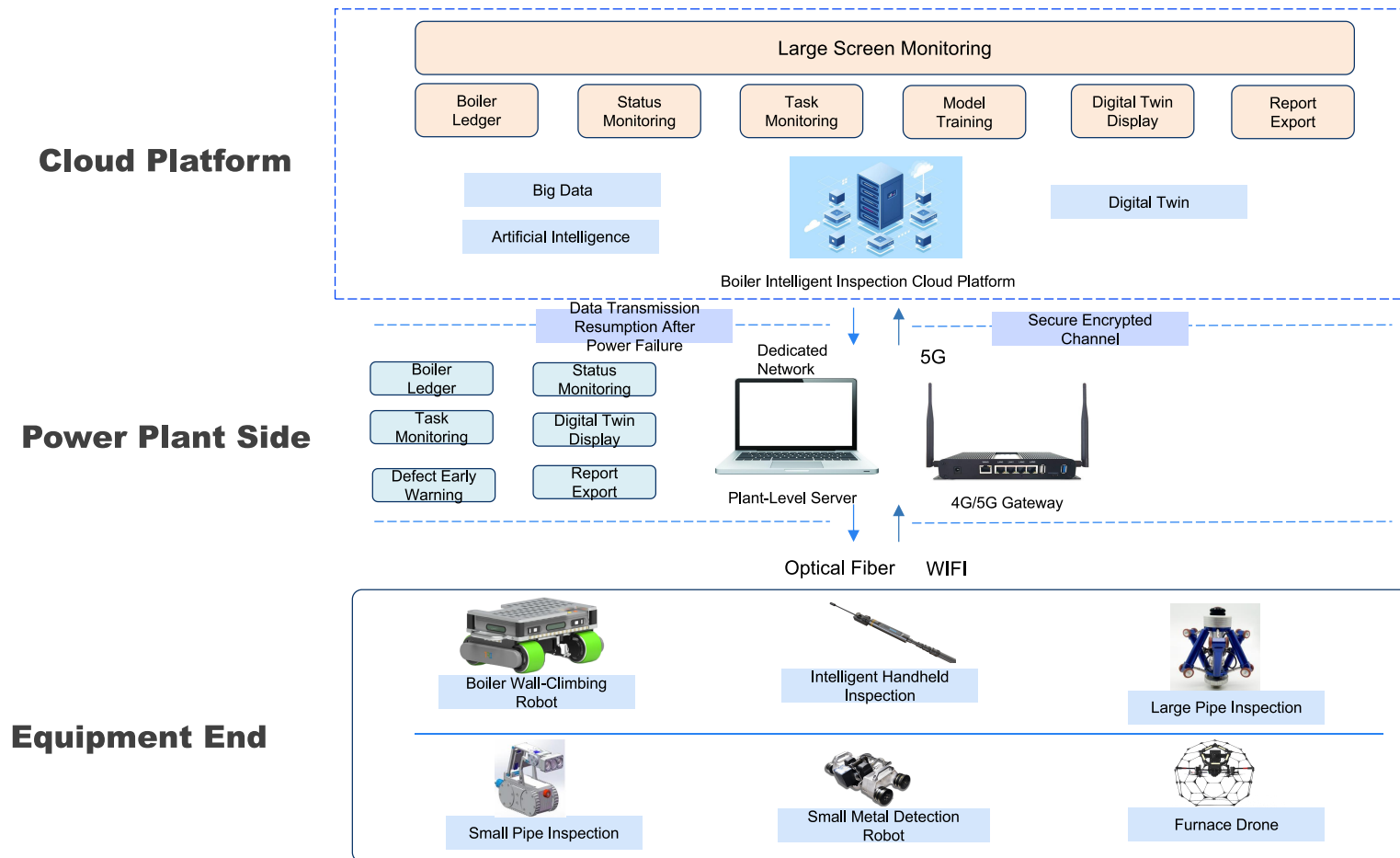
Accurately and efficiently understand the operating conditions, continuously optimize operating parameters, significantly reduce operating risks, and alleviate the daily workload of operation and maintenance personnel.



Result Demonstration



Boiler Intelligent Inspection Cloud-Edge-End Architecture



Boiler Water-Cooled Wall Inspection Robot System

1、Current Industry Situation



Application Scenarios, Characteristics

Boiler accidents account for 70% of total power plant accidents, and wall tube leakage accounts for 70% of boiler accidents. The inspection area of boiler water-cooled walls is over 10,000 square meters, including various tube types such as vertical tubes, spiral tubes, and 90-degree right-angle cross-sections.

Traditional Methods

- Manual Inspection
- Scaffolding/lifting machines, time-consuming to set up and dismantle;
- High-altitude operation, high risk to personal safety;
- With a wall tube surface area of over 10,000 square meters, manual high-altitude inspection using handheld devices, relying on personal experience for inspection and maintenance, high probability of missing inspections;
- Excel spreadsheets used to record ledger information, mobile phones used to take photos of defects inside the boiler, data is scattered and separated, no utilization value.

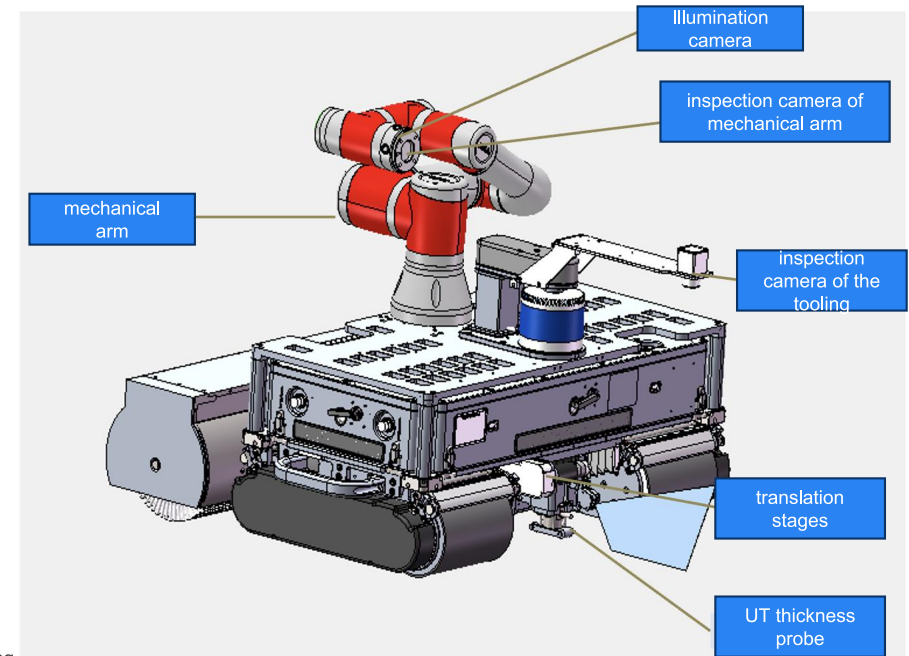
Maintenance Frequency

- Annual regular maintenance
- Unplanned temporary inspection

Maintenance Frequency

High-altitude operation using scaffolding and lifting platforms poses safety risks.

2、Robot Product



Boiler Water-Cooled Wall Inspection Robot System

3、Result Demonstration

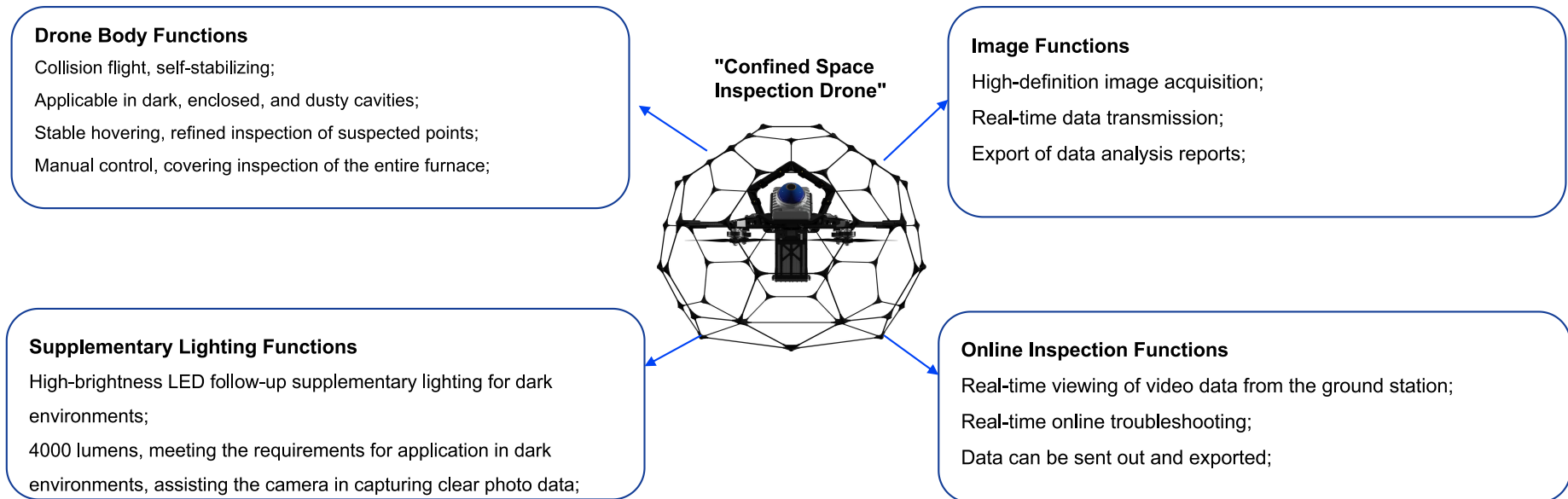


Boiler Macro Inspection Drone System

1、Current Situation and Goals

The drone system can operate safely and stably in dark, metal-enclosed, and dusty furnace environments, and can be equipped with industrial vision modules to perform inspection tasks. It can enable personnel to avoid climbing into high-altitude areas of the furnace, and remotely operate to complete data extraction inside the furnace. The operation is simple and intelligent, and the drone can also hover for work. The mobile carrier is equipped with necessary protective designs (anti-collision and anti-fall requirements), and can achieve real-time on-site transmission of data collected by the industrial vision module. It is expected to replace manual labor to complete rapid inspection of the furnace and intelligent image capture of relevant areas. Intelligent image analysis can be performed on the deformation of burner nozzles due to heat, ash accumulation and coking, as well as the deformation, corrosion, and ash accumulation and coking of the heating surface tube walls. A list of inspection defects can be generated in the background.

2、Product Introduction



Boiler Macro Inspection Drone System

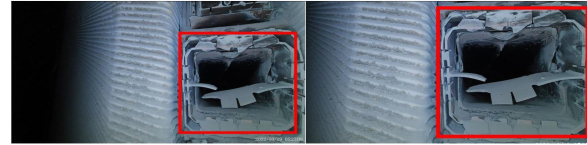
3、Technical Specifications

Serial No.	Item	Value
1	External Dimensions	460*460*360mm
2	Standard Take-off Weight	1.6kg
3	Standard Endurance	18-20min per flight (multiple battery packs can be replaced)
4	Maximum Take-off Weight	1.8kg
5	Collision Protection Form	360° quasi-spherical collision protection frame
6	Collision Protection Level	Effective for long-term at 0-3m/s speed Less than 3 times at 3-5m/s speed
7	Extreme Operating Range	1-100 meters
8	Flight Speed (Confined Space Flight)	0-1m/s (Operating Mode) 0-3m/s (Fixed Point Mode)
9	Camera Resolution	3840*2160@30fps
10	Supplementary Lighting Brightness	4000 lumens

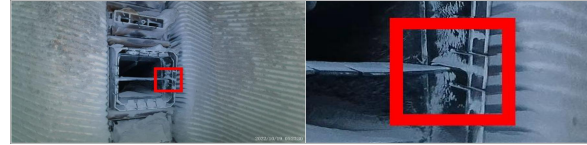
4、Result Demonstration

Boiler Inspection: Defect Reference and Report Reference

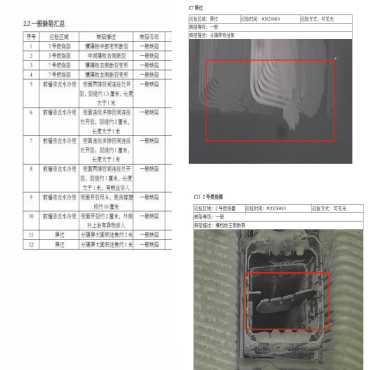
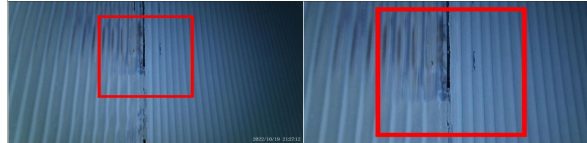
缺陷描述：横隔板中部变形断裂



缺陷描述：中间隔板右侧断裂



缺陷描述：壁面连续多排管间连接处开裂，裂缝约2厘米，长度大于1米



Intelligent Handheld Metal Positioning Detector

1、Current Situation and Goals

Currently, the sensors used for boiler wall tube inspection in power plants are mostly piezoelectric ultrasonic sensors. The inspection steps are divided into the following four:

- 1) Grind and polish the wall tube until the metal luster is exposed;
- 2) Spray a coupling agent at the grinding position, using water or oil coupling;
- 3) Tightly attach the piezoelectric ultrasonic sensor to the wall tube and move it left and right without any tilt angle, and record the thickness measurement position and data;
- 4) If defects are found, take photos with a mobile phone for record-keeping;
- 5) After returning to the office, enter the thickness measurement data into the computer.

The above steps have the advantage of accurate measurement data, but there are the following disadvantages:

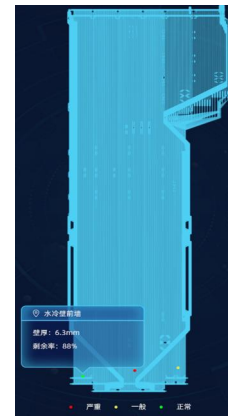
- 1、The steps of grinding, polishing, and applying coupling agent are cumbersome, affecting the inspection speed;
- 2、Taking photos and measuring thickness are completed in two separate steps, affecting the inspection speed;
- 3、The inspection position needs to be estimated based on experience, and the position is inaccurate;
- 4、Inspection and data entry work are separate, taking a long time;
- 5、Some narrow space tube walls cannot be inspected and need to be cut for inspection.

To solve the above five problems, our company has developed an intelligent handheld metal positioning detector, which uses electromagnetic ultrasonic sensors for thickness measurement, without the need for grinding, polishing, or water coupling. It uses laser radar for real-time positioning on the water-cooled wall surface, supports one-click photography and thickness measurement, and transmits data to the background software system in real-time. It features high efficiency, accuracy, convenience, and safety.

2、Product Introduction and Result Demonstration

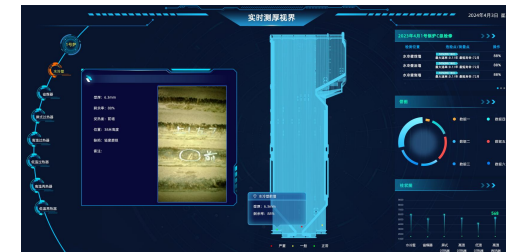


The boiler intelligent handheld positioning thickness measurement system is mainly used for wall tube thickness measurement in business scenarios such as water-cooled wall surface thickness measurement, reheater narrow area wall tube surface thickness measurement, and economizer narrow area tube wall thickness measurement. It consists of five modules: an electromagnetic ultrasonic sensor, a furnace positioning system, an intelligent monitoring telescopic device, a real-time data transmission system, and a thickness measurement data management software system.



Before using this system for thickness measurement, a three-dimensional visualization model needs to be created based on the boiler drawings for positioning the thickness measurement data in the software system. For the water-cooled wall scenario, the thickness measurement device is equipped with a laser radar positioning device and a self-developed navigation and positioning algorithm. It can perform real-time positioning based on the area selected by the current inspector in the system and their current location, and transmit the thickness measurement data together with the positioning data to the background management software system. After the thickness measurement data and positioning data are synchronized to the positioning thickness measurement data management software system, the real-time location of the thickness measurement points can be displayed in the three-dimensional visualization model of the boiler.

The system is equipped with a real-time data transmission system. The thickness measurement data and positioning data can be saved in the system in real-time. After the high-definition touch screen is connected to the intranet, the data can be synchronized to the positioning thickness measurement data management software system.



Telescopic Pipe Inspection Robot System

1. Business Scenarios



Used for macro inspection inside the pulverized coal pipes from the coal mill outlet to the burner inlet section. The robot needs to have independent crawling and adsorption structures as well as a backend management system. It should achieve crawling motion capabilities in horizontal, turning, slope, and vertical directions, and realize the functions of video and photo transmission from inside the pipe, as well as macro detection and inspection of pipe wall wear, ceramic tile shedding, expansion joints, etc.

2. Product Introduction



- 1、 Possesses independent crawling capability inside the pipe and can crawl inside the pulverized coal pipe from the coal mill outlet to the burner inlet section.
- 2、 Equipped with high-definition camera functionality and supports external function expansion.
- 3、 Has crawling motion capabilities in horizontal, turning, slope, and vertical directions.
- 4、 Power supply voltage $\leq 36V$ (meets safety requirements).
- 5、 The backend software system realizes the playback of videos and photos from inside the pipe, as well as macro detection functions such as pipe wall wear, corrosion, ceramic tile shedding, expansion joints, etc.

3. Technical Specifications

- 1、 Suitable pipe sizes: Inspection of pipes between DN100mm and DN700mm.
- 2、 Telescopic robot body:
 - 1) Horizontal and vertical crawling, carrying weight $\geq 5KG$.
 - 2) Crawler body reaches IP64 waterproof standard.
 - 3) Crawler body supports customization of various sizes.
 - 4) Wheels use high-performance anti-slip materials, suitable for free movement inside metal and non-metal pipes.
- 5) The rear end of the body uses high-strength anti-detachment protective steel cable to prevent the inspection line from detaching from the body under extreme conditions.
- 6) The front of the body has a high-brightness, anti-glare LED lighting system, which can provide sufficient video illumination in various types of pipes.
- 7) The body can be designed to carry other inspection probes and tooling for internal inspection.
- 8) The body can pass through tees and weld seams with a height of more than 10mm.
- 3、 Panoramic camera: Can be equipped with a 5-megapixel and 200° ultra-wide-angle lens.

4. Result Demonstration



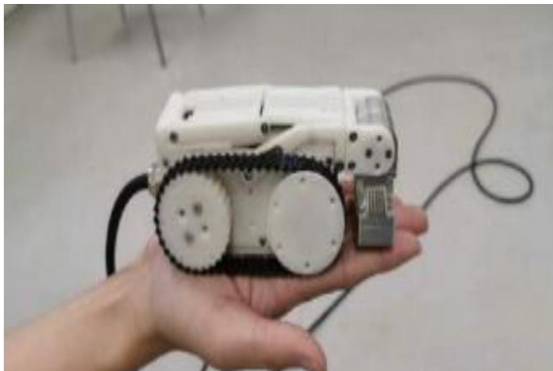
Small Magnetic Adsorption Pipeline Inspection Robot System

1. Business Scenarios

For video inspection work inside pipelines with small diameters or small openings in key parts of power plants, ordinary pipeline robots cannot enter. This robot adopts a highly integrated overall design and uses a lifting structure. After entering the pipeline through a small opening, it adjusts its height to obtain the best inspection field of view.

2. Product Introduction

The small pipeline inspection robot mainly consists of the robot body, a portable cable reel cart, and a back-end monitoring tablet computer. The robot body is equipped with a video inspection module with dual degrees of freedom for lifting and pitching, which can replace the endoscope for carrying out video inspection work inside the manifold.



3. Technical Specifications

- Realizes remote video inspection of the pipeline interior
- Applicable conditions: suitable for openings and pipelines above 80mm
- Gyroscope attitude monitoring, front laser reference line
- The overall size of the robot is approximately 50mm*60mm*150mm, capable of entering pipelines with a minimum of 80mm hand holes
- Inspection distance: 30-100 meters
- Field of view adjustment: 2 degrees of freedom for lifting and pitching
- Image clarity: dual cameras, front inspection module 1080p, rear environment monitoring 720p

4. Effect Demonstration

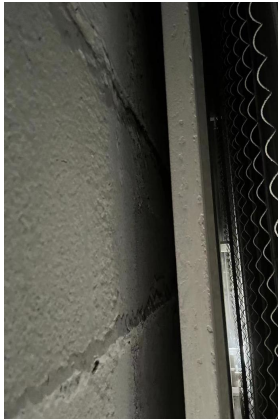
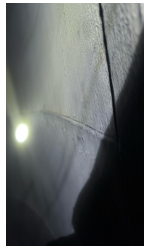


Small Magnetic Adsorption Pipeline Inspection Robot System

1、Current Situation



Chimney weld inspection



Thermal power
electrostatic precipitator
inspection



Wind power tower weld inspection

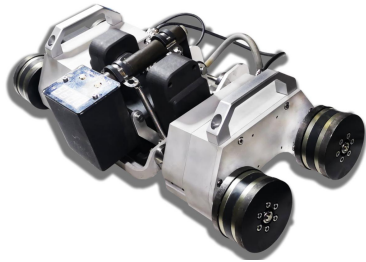
Technical parameters

Dimensions: 43cm long * 19cm wide * 13cm high
Speed: 0.2m/s
Weight: 12kg
Load capacity: 15kg
Camera: Video resolution of 2.1 megapixels, 1080P
Power supply: 220V power source and battery
Environmental operating temperature: 5°C to 40°C

Product features

1. Compact body, strong magnetic adsorption, suitable for various metal wall inspection scenarios such as thermal power, wind power, and hydropower
2. High-precision motion, supports free and flexible movement on walls
3. Multi-environment video signals, can collect external environment information and wall surface defect information
4. Portable integrated control system, easy to operate and convenient to deploy
5. Good scalability, can be equipped with different inspection devices

2、Robot Products

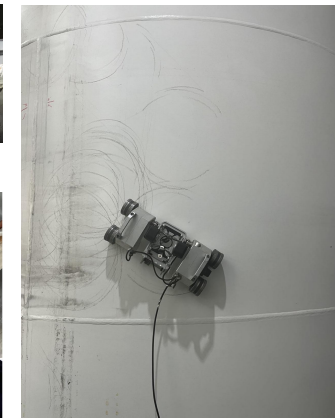
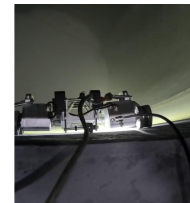


Robot body



Phased array
inspection tooling

3、Effect Demonstration



Coal Conveyor Corridor Inspection Robot

1. Current Situation



1. Corridor personnel inspections are easily affected by personal experience, emotions, and subjective consciousness;
2. Noise, dust, and ice formation in winter in the corridor pose health and safety hazards to inspection personnel;
3. Manual inspections are not systematic and comprehensive, unable to link with the start-stop system, existing corridor videos, fire protection, and other infrastructure, and cannot effectively carry out comprehensive analysis;
4. The robot inspection environment is harsh, with heavy coal ash, requiring high stability of hardware equipment;
5. Manual inspections are constrained by monitoring methods, data recording, and data analysis. Usually, a lot of manpower is spent but effective data results cannot be obtained, and the data obtained is difficult to form a systematic and meaningful reference.

2. Solution



Applicable Scenarios:

Power plants, coal mines, smelters, and other complex material conveying corridors, trestles, etc., with multiple inspection tasks, high-risk, and long-distance scenarios.

Core Functions

- Equipment abnormality monitoring
- Belt tear detection
- Gas/dust detection
- Temperature and humidity monitoring
- Idler abnormality detection
- Real-time IP voice intercom
- Personnel, living creature intrusion/personnel safety supervision
- Local overheating monitoring
- Belt displacement and deviation detection
- Material conveying and pile-up detection
- Voice pattern analysis and abnormal sound detection, etc.

3. Core Features

I. Full-scene monitoring of coal conveyor belt:

1. Real-time quantitative monitoring and fault prediction of belt deviation;
2. Monitoring and alerting of foreign objects invading the belt conveyor;
3. Monitoring and location alerting of coal spillage on the side of the belt conveyor;
4. Infrared temperature measurement and alarming of idlers and rollers along the entire coal conveying belt line;
5. Belt deviation at key points of the coal conveying belt line;
6. Intelligent identification and alarming of coal blockage at key points of the coal conveying belt line;
7. Real-time monitoring of dust concentration in the trestle, and alerting when the limit is exceeded;
8. Collection and feedback of concentrated heat, smoke, and open flame information inside the trestle;
9. Safety analysis models such as personnel falling and not wearing safety helmets.

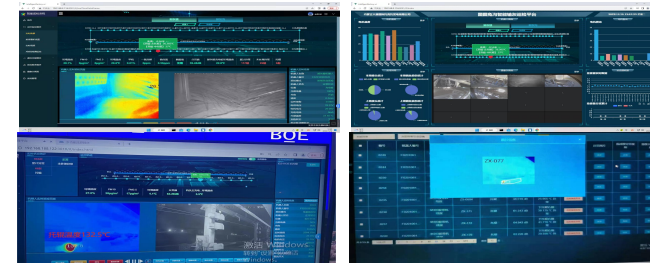
II. Integrated operation environment of coal conveyor corridor and linkage early warning

1. Integration and linkage with the belt start-stop system;
2. Seamless integration and linkage with the on-site video surveillance system;
3. Seamless integration with the belt tear detection device;
4. Seamless integration and linkage with the on-site fire protection system.

III. Support from mobile terminals, big data, and artificial intelligence technology

1. Supports online monitoring through mobile terminals;
2. Long-term storage of big data such as time-series data and video data;
3. Built-in artificial intelligence analysis and control platform, supporting capabilities such as training set annotation, model training, and model operation.

4. Effect Demonstration



Factory/Substation Inspection System

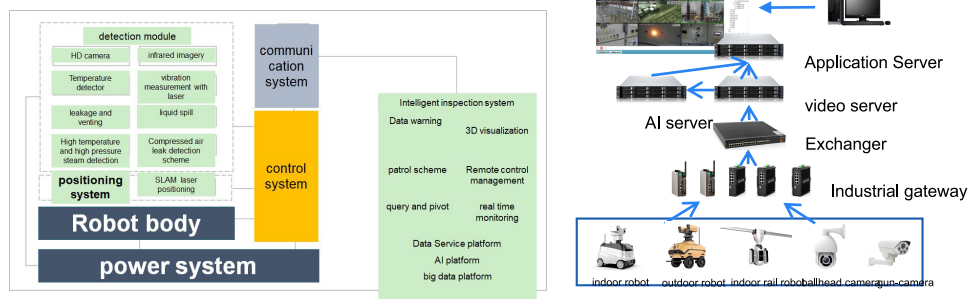
1. Current Situation

	Manual Inspection
Inspection Method	Inspection personnel go to the site, use handheld infrared thermal imaging equipment for temperature measurement and manually record data from meters. After completion, they manually export equipment photos and re-enter the paper record data into the inspection point system.
Workload	The scope of inspection work, each complete manual inspection requires at least 2-4 hours.
Objectivity	Manual inspections have variability due to inspection personnel, inspection angles, inspection times, etc., resulting in differences in data objectivity.
Accuracy	The infrared temperature measurement data is similar to that of robots. The accuracy of meter reading is affected by distance, meter position, reading angle, and reading errors. Manual reading has advantages in individual cases where robots have difficulty identifying and reading due to angle and position.
Real-time	There is at least a 2-3 hour delay from manual inspection to data reporting.
Convenience	Multiple inspections are required every day, with a heavy workload. When encountering severe weather such as thunderstorms and strong winds, personnel cannot enter the equipment area for inspection.
Defect Tracking Comparison	Defective equipment requires regular and timely manual inspection.

2. Solution

The system includes various intelligent hardware in the perception layer, including indoor inspection robots, outdoor inspection robots, indoor rail-mounted inspection robots, and various cameras.

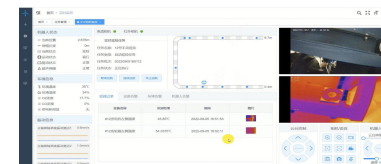
The intelligent hardware transmits real-time monitoring data and video to the server through industrial gateways deployed in the factory. Monitoring personnel can control the situation in each area of the factory and the inspection status of the robots through computers in the control room.



3. Core Features

1. Product series refinement: From large to small robots; from operating in normal environments to extreme environments.
2. Strong image recognition capability High inspection recognition rate: infrared recognition rate reaches above 98%, visible light recognition rate reaches above 95%; Meter recognition in abnormal situations: tilted, occluded, reflective, dirty, foggy Appearance defect recognition: Supports recognition of more than 30 different defects; Supports special environments: night, rain, snow.
3. Supports visible light and infrared inspection while moving
4. High-precision navigation and positioning technology, fully adopting 3D laser SLAM navigation and environment-adaptive matching algorithms to ensure reliable operation in dynamically changing environments.
5. Power frequency and radio frequency electromagnetic field anti-interference, robots undergo power frequency electromagnetic field immunity tests and radio frequency electromagnetic field immunity tests before leaving the factory. The power frequency electric field and power frequency magnetic field in the inspection site will not affect the normal use of the robot.
6. Big data platform and artificial intelligence analysis, the robot inspection software uses a big data platform to store real-time sensor data and video image file data. The back-end data analysis and mining uses an artificial intelligence analysis and control platform for data modeling, realizing real-time data alarm analysis.

4. Effect Demonstration



Personnel Intrinsic Safety System

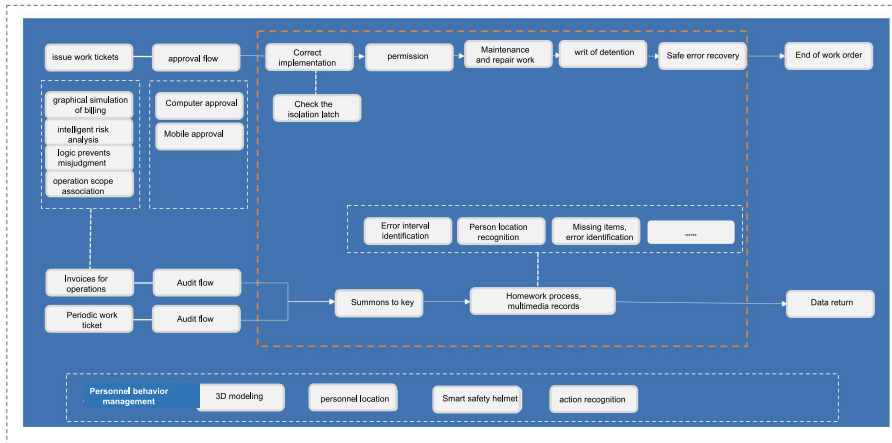
1. Current Situation



- 01 Lack of risk sources and risk pre-control plans; untimely risk identification, risk assessment, and risk early warning management and control.
- 02 Lack of uniformity and standardization in hidden danger investigation
- 03 Low reliability of safety supervision in high-risk areas such as confined space operations
- 04 Daily maintenance and repair operations of outsourced teams involve a wide range of work areas and many personnel
- 05 Difficult to control the phenomenon of expired qualification certificates and work tools of on-site personnel
- 06 Inability to effectively supervise and count the arrival and presence of personnel
- 07 Lack of a centralized safety early warning display platform, unable to effectively implement safety management

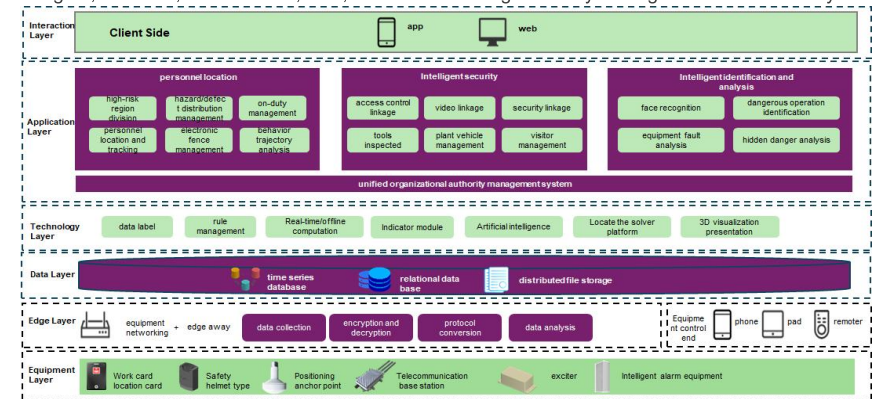
2. Solution

■ Safety management and control of on-site operations based on the two-ticket management

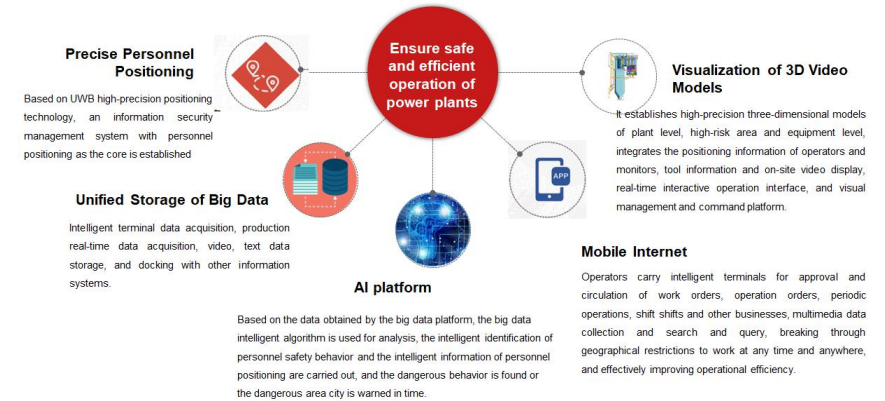


■ Core functions

The intelligent safety management and control cloud platform is supported by personnel positioning, big data, digital twins, and artificial intelligence technologies. It realizes full coverage of safety management for on-site operation personnel in power plants, timely detects and provides early warning of hidden safety hazards in operations, and effectively controls safety risks. It establishes an intelligent, real-time, standardized, safe, and reliable intelligent safety management and control system.

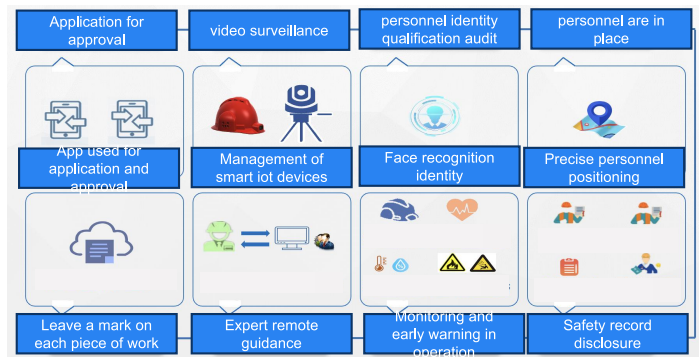


■ Core technologies for personnel intrinsic safety management and control

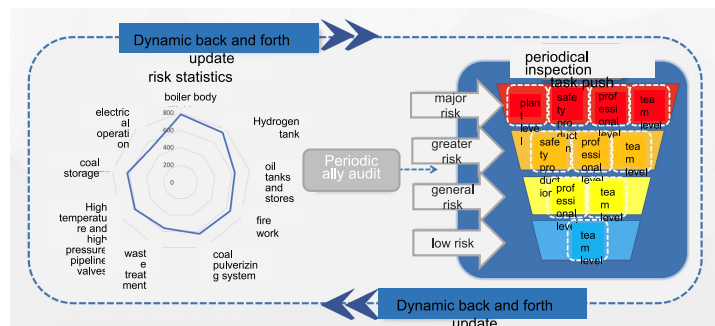


Personnel Intrinsic Safety System

■ Safety management and control throughout the entire process of high-risk operations



■ Risk classification and hidden danger investigation



■ Precise personnel positioning



■ Trajectory playback



Through electronic maps, managers can grasp the location of personnel in the controlled area, personnel distribution density, corresponding status information, and the activity trajectory of each controlled target at any time.

■ Electronic fences

The system implements zoned area management, which facilitates accurate positioning of alarm areas. At the same time, each defense zone can be conveniently armed and disarmed, and can be automatically activated or automatically disarmed according to time.

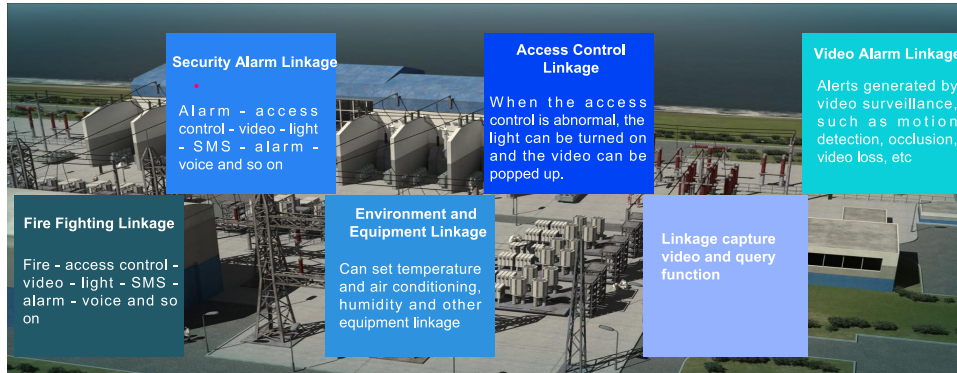
The alarm sensitivity can be flexibly set to ensure an extremely low false alarm rate while being able to distinguish between accidental contact and forcible intrusion.

It has linkage functions with auxiliary production systems such as lighting control systems and video surveillance systems.

Combined with electronic fences, it conducts area personnel statistics and realizes the identification of personnel gathering and the presence of accompanying personnel.

Personnel Intrinsic Safety System

■ Video linkage

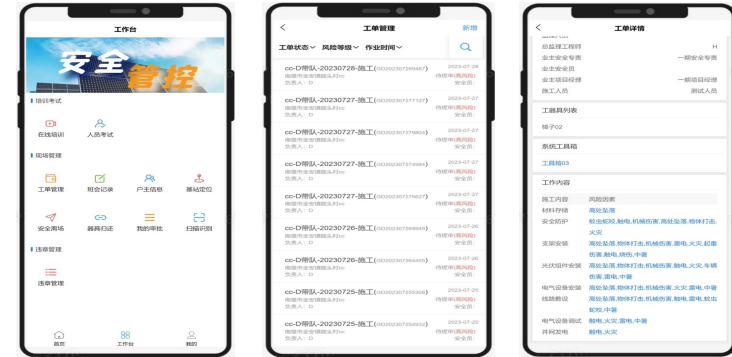


■ 3D visualization display technology



- Oblique photogrammetry modeling of plant area
- Precise 1:1 modeling of equipment
- Personnel localization, behavior
- Electronic fence, safety alert
- Safety VR training
- Playback of personnel walking trajectories

3. Effect Demonstration



Indoor precise positioning

Through high-precision positioning terminals and architectural design and application, the positioning and tracking of personnel and mobile equipment in substations is achieved by means of wearable positioning terminals and object-mounted positioning terminals.

Integration of five security systems

Through spatio-temporal correlation analysis of location information, and integration with the five security systems, management and predictive warning of operations by unauthorized personnel, personnel entering wrong areas, and operations outside permitted time periods are achieved.

Integration of two-ticket system

Seamless integration with the two-ticket system enables seamless integration for periodic maintenance and patrol operations. Through precise UWB positioning of personnel locations, functions such as indoor route planning, deviation warnings, and long stationary warnings in power plants are realized.

Linkage with access control and video surveillance

Through autonomous linkage of location information and video, real-time tracking and control of personnel entering through the second gate and personnel performing risk operations is achieved within the entire plant area. Combined with image recognition results, active alerts are triggered for personnel misconduct, enabling full-process risk monitoring at the work site.



02

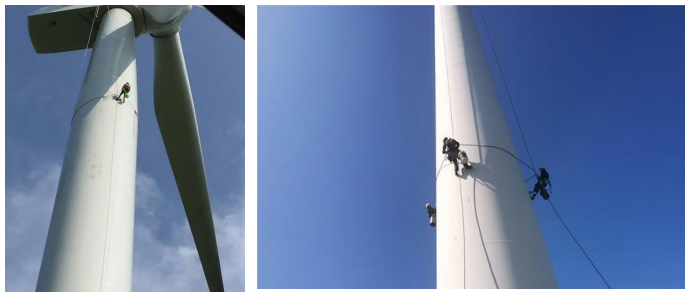
Unmanned Wind Farm

- Wind turbine tower cleaning and inspection robot system
- Wind turbine nacelle inspection robot system
- Wind turbine blade exterior inspection robot system
- Wind turbine blade interior inspection robot system
- Unmanned intelligent management and control system for wind farms

Wind Turbine Tower Cleaning and Inspection Robot System

1. Current Status of Wind Turbine Tower Cleaning and Inspection

The overall shape of the wind turbine tower is a tapered conical cylinder, with protruding obstacles in the form of longitudinal welds and annular welds on the surface. Maintenance operations include tower cleaning to remove oil stains and weld inspection under two working conditions. Currently, high-altitude work is generally carried out using suspended cradles or rope access technicians (spider men). Movement is achieved through manual hauling from below, resulting in low work efficiency, significant safety hazards, and high labor costs.



2. Wind Turbine Tower Cleaning and Inspection Robot System



3. Product Features

- Supports highly efficient fully automatic cleaning capability
- Equipped with descaling, repainting, and weld inspection capabilities
- Utilizes a mobile internet platform with cloud management, enabling remote command, monitoring, and real-time video control
- Allows viewing of on-site conditions, timely information feedback and tracking, real-time operation recording, and clear status visibility
- Applies big data technology to establish a digitized maintenance record for the tower

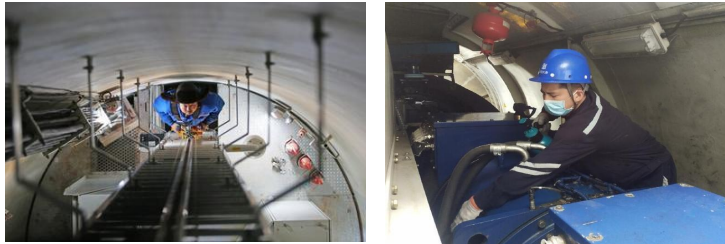
4. Operation Video Footage



Wind Turbine Nacelle Inspection Robot System

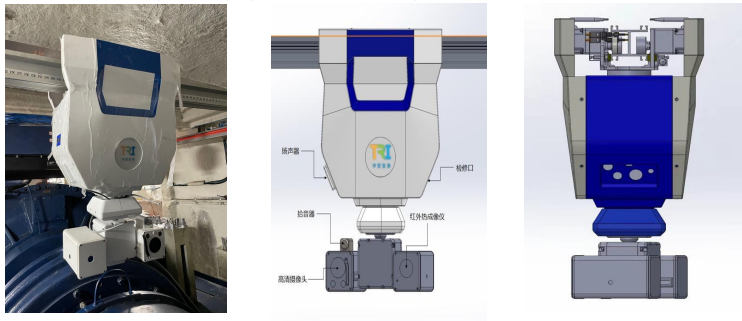
1. Current Status of Wind Turbine Nacelle Inspection

Currently, wind turbine nacelle inspection is conducted solely through manual means. This method has several issues - high cost per inspection, low inspection frequency, poor real-time performance, and personnel safety risks. Additionally, due to manual operation, inspection data cannot be transmitted in real-time to the backend for unified analysis and processing.



2. Wind Turbine Nacelle Inspection Robot System

The product operates on a rail-mounted system and is equipped with various sensors such as temperature, vibration, sound, and tilt sensors to achieve multi-dimensional real-time online monitoring of the wind turbine nacelle and tower. This addresses issues such as low inspection frequency and personnel safety concerns. The system can perform the following functions: temperature monitoring, gauge reading recognition, leak detection, personnel behavior recognition, environmental recognition (e.g., smoke, flames), and abnormal equipment noise detection.



3. Product Features

- Equipped with infrared camera and high-definition visible light camera
- Equipped with an elevating pole and rotatable pan-tilt head
- Integrated microphone
- Supports data transmission via 4G/5G or WiFi
- Digital twin 3D visualization monitoring system
- Supports real-time storage of massive sensor data

4. Operation Video Footage



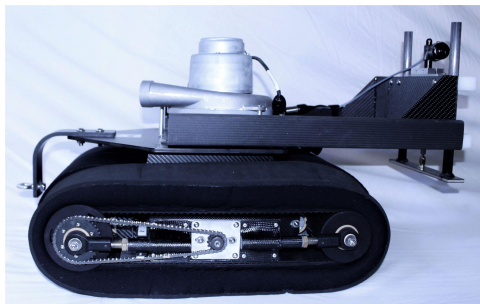
Wind Turbine Blade Exterior Inspection Robot System

1. Current Status of Wind Turbine Blade Exterior Inspection

Wind turbine blades are heavily impacted by wind erosion during operation, and their protective surface layers are prone to damage, leading to dust accumulation and encrustations, which severely affect power generation efficiency. The high-altitude rotation of the blades also exposes them to greater risks from lightning, hail, rain, snow, sand storms, and hurricanes. If cracks are not detected in a timely manner, they can extend into the fiberglass layers, resulting in significant damage. Many wind farms frequently operate with damaged blades, posing safety hazards. In recent years, serious wind turbine accidents, and even casualties, have occurred frequently due to blade damage. Blade inspection is an unavoidable issue that must be addressed.



2. Wind Turbine Blade Exterior Inspection Robot System



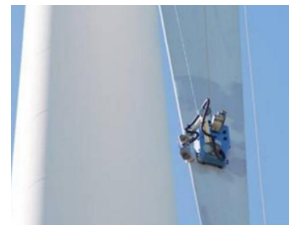
The vacuum adhesion robot system is equipped with high-definition video cameras, ultrasonic inspection devices, image transmission, communication, and storage equipment and instruments, enabling comprehensive inspection of wind turbine blades. The inspection results are summarized and presented in a visualized, systematic, and standardized manner to maintenance personnel, technical experts, and management staff. This system increases inspection efficiency by over 40% and saves approximately 3.2 million yuan in costs annually.

3. Product Features

The vacuum adhesion robot system adopts a robotic approach to replace manual labor for wind turbine blade inspection. It can be equipped with high-definition video cameras, ultrasonic inspection devices, image transmission inspection instruments, communication and storage equipment, enabling comprehensive inspection of wind turbine blades as well as rapid focused inspection of critical areas. The relevant inspection results are summarized and presented in a visualized, systematic, and standardized manner to maintenance personnel, technical experts, and management staff, providing assistance in eliminating safety hazards and enabling scientific decision-making.

- Vacuum adhesion technology
- Ultrasonic phased array inspection technology
- Artificial intelligence positioning and navigation
- Robot supports remote control
- Adapted for diverse climate environments

4. Operation Video Footage



Wind Turbine Blade Interior Inspection Robot System

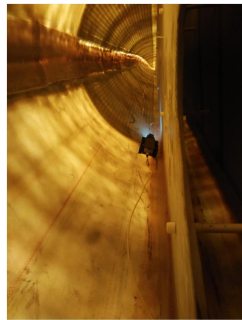
1. Current Status of Wind Turbine Blade Interior Inspection

Wind power has become China's second-largest clean and renewable energy source after hydropower. During operation, wind turbine blades are heavily impacted by wind erosion, and their protective surface layers are prone to damage, leading to dust accumulation and encrustations, which severely affect power generation efficiency. The high-altitude rotation of the blades also exposes them to greater risks from lightning, hail, rain, snow, sandstorms, and hurricanes. These harsh external environments can cause defects such as bulging, wrinkles, delamination, and cracks inside the blades after a period of operation. Currently, manual periodic inspections are the primary method, which can lead to missed inspections, misidentifications, incomplete inspections, and incomplete record-keeping. Additionally, the harsh working environment and high-altitude operations pose safety risks.

2. Wind Turbine Blade Interior Inspection Robot System

The robot system consists of a controller, cable reel, and crawler. The crawler carries a camera into the interior of the blade, traveling along the blade cavity or shear web, capturing images and photographs. The data is transmitted through cables to the controller for display and storage.

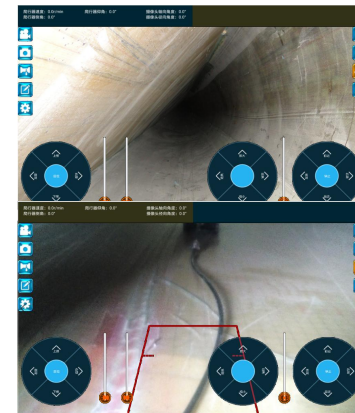
It can inspect the adhesion between the shear web and shell, as well as inspect the condition of the mold paste. It can also inspect defects such as wrinkles and cracks in the glass fiber on the shell.



3. Product Features

- Excellent hill-climbing and obstacle-crossing capabilities
- Multiple protection designs against overcurrent and overload
- Portable, two sets of different-sized wheel combinations for strong obstacle-crossing ability and flexible steering
- 2-megapixel digital HD camera, with 360° rotating lens
- Built-in auxiliary lens defogging function
- Laser ruler to assist in measuring defect areas
- Smartphone app and tablet control
- Counting correction and inspection report generation

4. Operation Video Footage



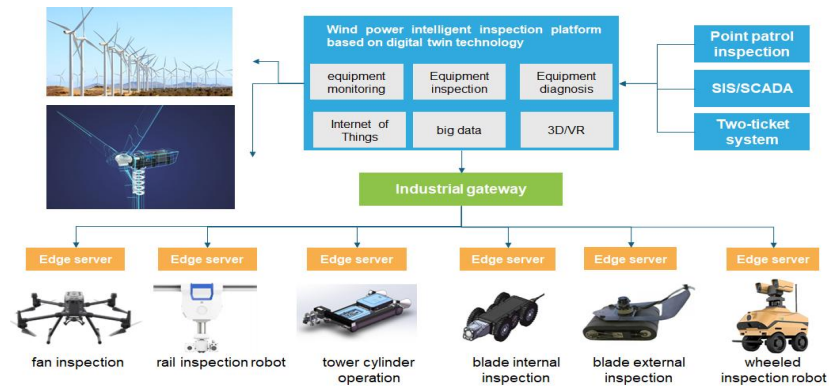
Wind Turbine Blade Interior Inspection Robot System

1. Current Status of Wind Farm Operation and Maintenance

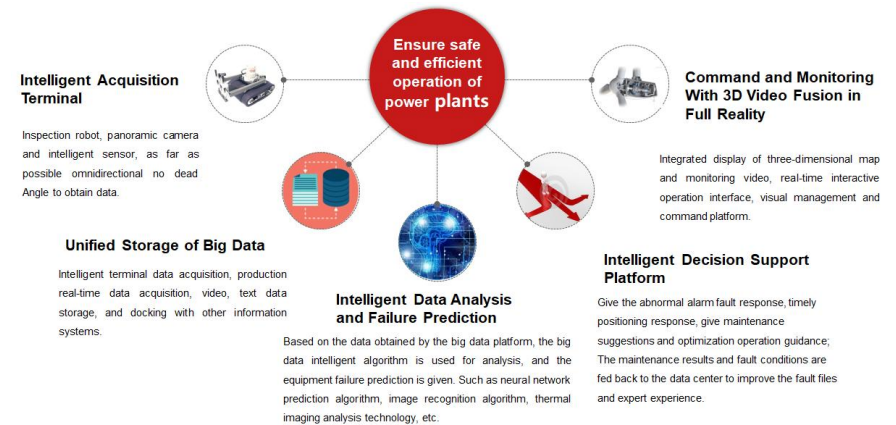
With the rapid development of the wind power industry, the mode of wind power production and operation has also changed, shifting towards centralization, sharing, and intelligence. Based on technologies such as the Internet of Things, big data, artificial intelligence, and robotics, the intelligent operation and maintenance management system for wind farms has realized centralized management of wind turbine sensor data, external environmental information, robot inspection information, and routine equipment records. The centralized data management further promotes intelligent business analysis for wind farms, intelligent inspection of wind turbines, health management of wind turbine equipment, and personnel safety management, gradually achieving operational automation and intelligence, realizing the goal of transitioning wind farms from minimal staffing to unmanned operations.

2. Intelligent Unmanned Management and Control System for Wind Farms

Based on big data, artificial intelligence, digital twin, and robotics technologies, the system provides core capabilities such as online monitoring and warning, intelligent equipment diagnostics, and intelligent equipment inspections for the three core components of wind turbines: blades, towers, and nacelles.



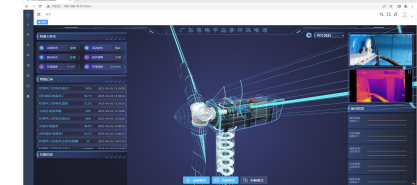
3. System Features



4. System Feature Showcase



Overall overview of wind farm turbines



Digital twin of wind turbines



Image recognition for wind turbines



Real-time monitoring and remote control of robots



Unmanned Photovoltaic Plant

- Distributed photovoltaic cleaning robot
- Centralized photovoltaic cleaning robot
- Intelligent unmanned management and control system for photovoltaic plants

Distributed Photovoltaic Cleaning Robot

1. Current Status of Distributed Photovoltaic Panel Cleaning and Maintenance



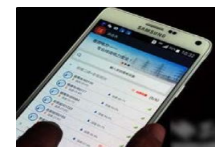
Under the backdrop of China's "dual carbon" policy, the photovoltaic industry has embraced development opportunities in recent years, with an increasing number of new photovoltaic projects being built annually. However, as these projects are implemented, the difficulty of cleaning photovoltaic panels has gradually been exposed: at fishery-photovoltaic complementary power plants, bird droppings accumulate severely on the photovoltaic modules, easily causing hot spot effects and affecting module lifespan; the complex water environment makes manual cleaning difficult and highly dangerous; agricultural-photovoltaic complementary power plants and distributed photovoltaic power plants require high-altitude work, posing significant safety hazards for manual cleaning.

3. Product Features

- Self-learning image recognition platform based on big data computing
- ZIGBEE-based ad-hoc self-organizing network control technology
- Hot spot detection on panels through array-style temperature scanning
- Remote video inspection for structural damage
- Visual recognition of bird droppings and other foreign objects, with water-based cleaning



Operation and maintenance management platform



Mobile client



Dust sweeping



Foreign object recognition

2. Distributed Photovoltaic Cleaning Robot

Maximum cleaning efficiency up to 2880 m²/h

Power generation efficiency increased by 30% after cleaning!



4. Operation Video Footage



Can be used for all kind of solar panels' cleaning and maintenance



Suitable for wet and dry cleaning



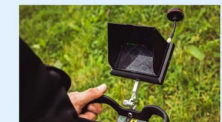
High cleaning efficiency, max speed is up to 40m/min



Controlled remotely to keep operators away from danger.



Multiple brushes which are suitable for all kinds of stains



LCD screen is used for monitoring, and can support a remote control of 100 meters away

Centralized Photovoltaic Cleaning Robot

1. Current Status of Centralized Photovoltaic Panel Cleaning

Centralized photovoltaic power plants often adopt manual cleaning modes for maintenance cleaning. However, manual cleaning has several shortcomings:

1. Centralized photovoltaic plants are generally constructed in remote areas with sparse populations, making personnel access inconvenient.
2. To shorten the duration of a single cleaning cycle, a large number of cleaning personnel must be hired, resulting in labor-intensive operations and difficult personnel management.
3. Even skilled cleaning teams exhibit differences in cleaning levels, making the cleaning process difficult to control and leading to inconsistent cleaning results and varying degrees of panel cleanliness.
4. Improper operations during manual cleaning can easily cause abrasion of the component glass, affecting the light transmittance and lifespan of the photovoltaic panels, thereby impacting the power generation rate of the photovoltaic plant.



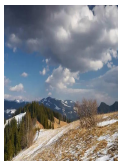
2. Centralized Photovoltaic Cleaning Robot

Targeting the geographical characteristics of centralized photovoltaic and solar thermal power plants, and considering the cleaning requirements of photovoltaic modules, this intelligent tracked robotic arm system for photovoltaic panel cleaning has been developed based on extensive research on existing cleaning machinery. It features a flexible main platform that can actively self-level and adapt to both longitudinal and lateral slopes. The robot has autonomous and automatic recognition capabilities for the working environment, and the cleaning device can automatically adapt its operations.

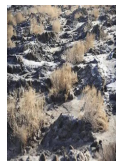
Terrain
Adaptability



Pebbles



Snow



Saline-alkali soil



Riverbed



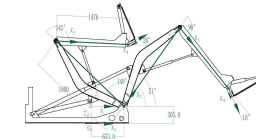
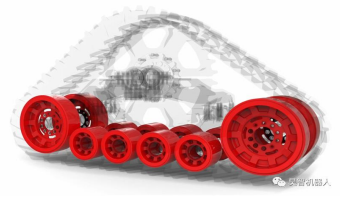
Sandy soil



Muddy ground

3. Product Features

- Achieves smooth operation, powerful driving force, and robust obstacle crossing capability;
- Autonomous sensing and adjustment;
- High safety and reliability;
- High cleaning efficiency and good cleaning results;
- High cleaning efficiency of 6000 m²/h, 30 times higher than manual cleaning, with up to 98% cleaning effectiveness;

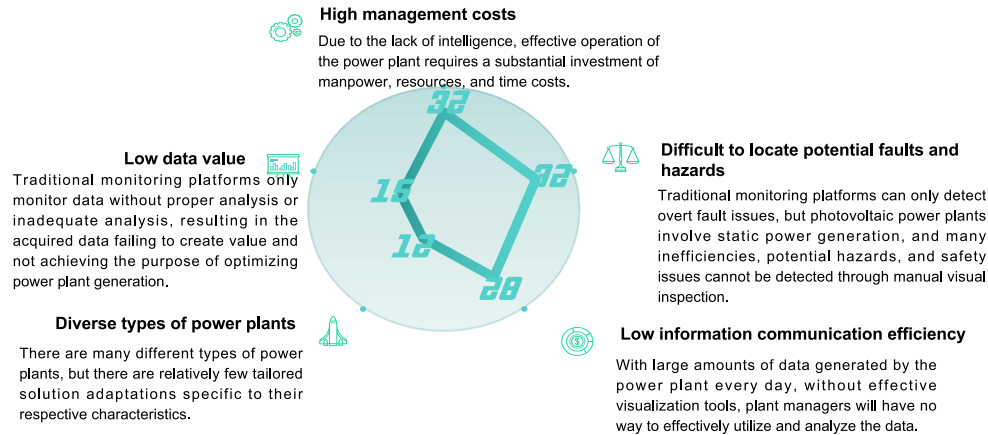


4. Operation Video Footage

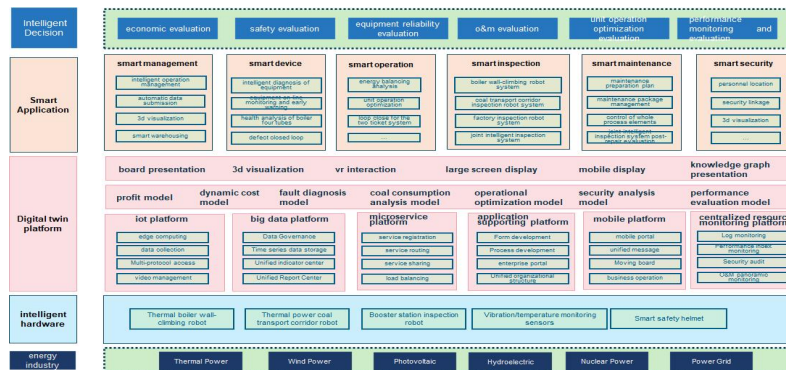


Intelligent Unmanned Management and Control System for Photovoltaic Plants

1. Current Status of Photovoltaic Plant Management



2. System Architecture



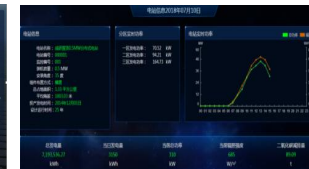
3. Core Features

- (1) It adopts an open distributed cluster architecture design, solving the issue of large-scale access for photovoltaic plants. It enables centralized management and real-time monitoring of the operational status of photovoltaic plants.
- (2) Through the operational information of various equipment at the photovoltaic plant and system modeling, the smart photovoltaic cloud performs big data mining and analysis on the entire plant to detect potential issues in advance.
- (3) The system can precisely locate faults at the photovoltaic plant, enabling automated operation and maintenance, reducing power generation losses, and lowering maintenance costs.
- (4) It provides intelligent robotic cleaning solutions for both distributed and centralized photovoltaic systems, significantly improving cleaning efficiency, reducing cleaning costs, and increasing power generation.
- (5) The photovoltaic unmanned system can reduce safety risks for personnel during construction and maintenance periods of photovoltaic plants.

4. Results Showcase



Comprehensive monitoring of photovoltaic plant



Power plant information monitoring



Overview monitoring of photovoltaic plant



Inverter operation monitoring



Array distribution operation monitoring



Inverter diagram

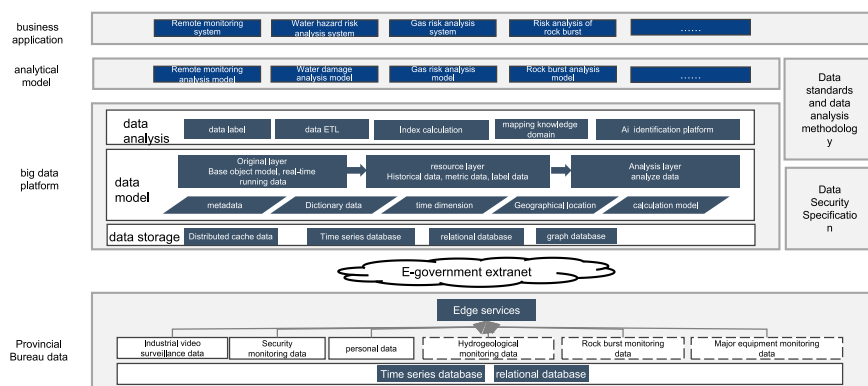
04

Solutions for Coal/Petrochemical/Steel and Other Industries

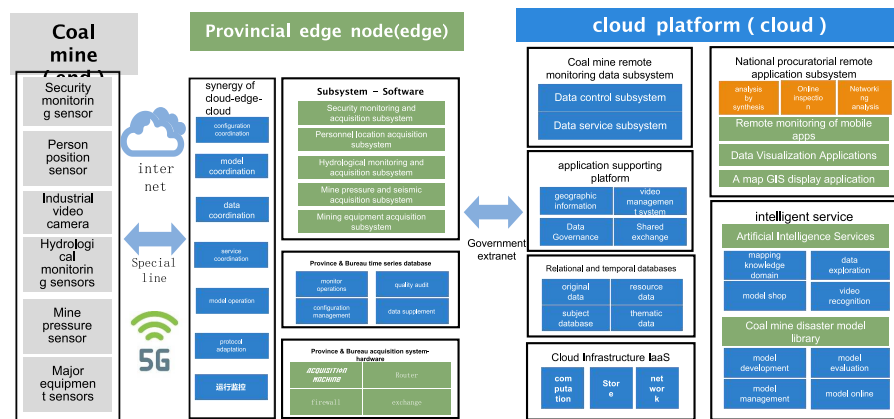
- Integrated data platform for remote monitoring of coal mine safety
- Intelligent joint inspection platform for coal preparation plants and coal washing plants
- Intelligent unmanned inspection platform for blast furnaces in the steel industry
- Intelligent joint inspection platform for the petrochemical industry

Coal Industry Safety Remote Monitoring Integrated Data Platform

1. Platform overall architecture



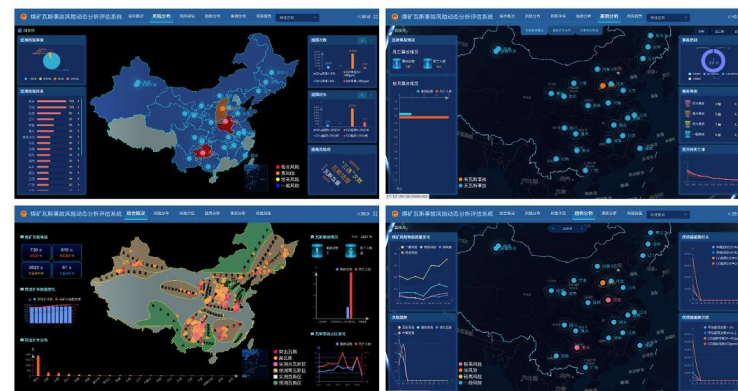
2. Platform features - cloud/edge/end architecture



3. Coal mine safety production intelligent monitoring and early warning system demonstration



4. Coal mine disaster analysis system demonstration



Intelligent Joint Inspection Platform for Coal Preparation Plants and Coal Washing Plants

1. Industry Status

- Inspections rely mainly on manual labor, posing safety hazards, with low inspection frequencies in remote areas.
- Lack of intelligent visual recognition capabilities, relying on human detection, unable to automatically identify and read data.
- Singular video monitoring approach with cameras, lacking multi-dimensional inspection with other sensors, such as gas monitoring, partial discharge monitoring, etc.
- Indoor/outdoor inspection, fire protection, monitoring and other systems are fragmented, unable to form a unified monitoring system.
- Inspection results are stored in paper or Excel formats, not saved and archived within software systems, preventing data analysis and traceability.

3. Platform Value



2. Platform Introduction

The solution integrates multiple intelligent devices and scenarios into a unified software system, building a joint inspection platform. It introduces robots to replace manual labor, reducing labor costs and personnel safety risks. It forms an inspection system combining periodic robot inspections and real-time sensor monitoring. Leveraging the mobility of robots and their ability to carry sensors, it increases the variety of inspection and detection data. Utilizing artificial intelligence models, it enhances the intelligence level of robot inspections, creating an unmanned inspection platform capable of equipment abnormal noise monitoring, integrated smart fire protection, integrated video monitoring systems, and more. This meets the enterprise's intelligent inspection needs. Inspection data is centrally collected and stored, forming a big data repository for inspections.

4. Results Showcase



Intelligent Unmanned Inspection Solution for Blast Furnaces in the Steel Industry

1. Industry Status

For monitoring the temperature change trends of the tuyere platform's direct blowing pipes, detecting coal gas leaks, and the loud noises caused by burnt-through direct blowing pipes, the industry currently relies heavily on dedicated personnel using handheld instruments to monitor the high temperatures and leaks inside the blast furnace body. However, manual inspection methods have limitations, lack precision, have inconsistent measurement points, and are prone to issues like data deviations and missed measurements. This makes it difficult to comprehensively and accurately grasp phenomena like high temperatures and leaks inside the furnace body. Additionally, when personnel conduct inspections near the furnace body, they face extremely high safety risks.

Adopting an unmanned inspection robot to carry out inspections on the tuyere platform combines the flexibility and intelligence of manual inspections while overcoming and compensating for the deficiencies and shortcomings of manual methods. It is an important initiative for smart production and equipment safety assurance.

3. Core Functions

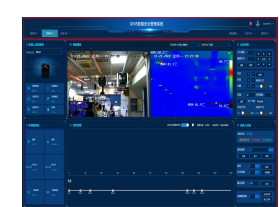
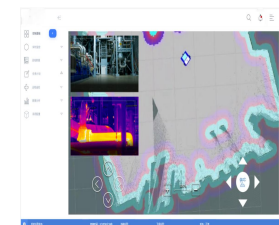
- Intelligent image recognition;
- Infrared thermal imaging;
- Equipment status recognition;
- Recognition of leaks;
- The robot can achieve fully automatic inspection operations or be remotely controlled from a PC terminal;
- Data collected by the robot can be transmitted to the backend platform;
- Data analysis capabilities to effectively detect and send alerts for abnormal situations like leaks, temperature, and sounds at the site.

2. Intelligent Blast Furnace Inspection Robot

The intelligent inspection robot system adopts a solution combining multiple terminal devices and management systems. It integrates cutting-edge technologies such as computer programming, AI image recognition and positioning, pattern recognition, wireless signal transmission, intelligent control, electromechanical control, and multi-sensor fusion. Encompassing software, mechanics, electronics, control, sensing, and materials disciplines, it collects data from images, sounds, temperatures, gases, and more to achieve comprehensive inspections without blind spots or omissions, realizing intelligent blast furnace inspections. This reduces the labor intensity for production and management personnel, freeing them from repetitive and inefficient labor to engage in higher-level analysis and management tasks.

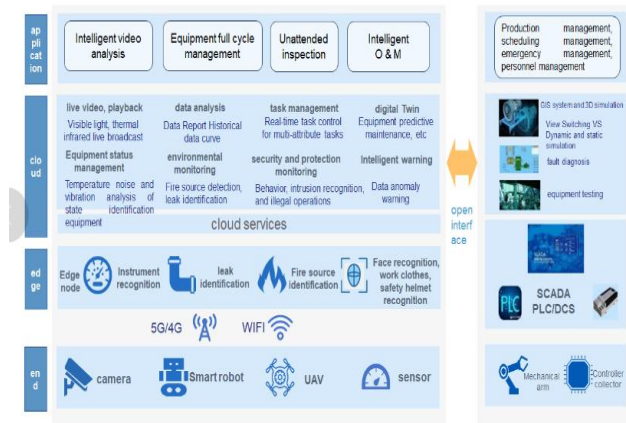
Wheeled inspection robots are deployed on the blast furnace tuyere platform to conduct on-site equipment temperature detection (accuracy of $\pm 2^{\circ}\text{C}$), CO concentration detection (0.5 ppm accuracy), equipment casing crack detection (98% accuracy), small trough liquid leakage detection (95% accuracy), smoke detection, and abnormal sound detection.

4. Results Showcase



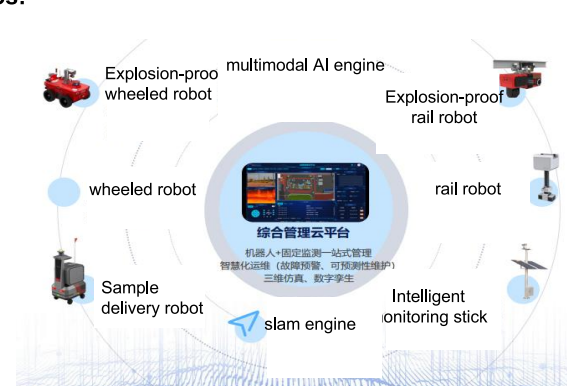
Intelligent Joint Inspection Solution for the Petrochemical Industry

1. Solution Description



2. Solution Features

1 platform + 2 engines + n intelligent products



- End-to-end system security, network security, data security, manageability
- Adapted and toolized for daily inspection operations of petrochemical enterprises
- Manageable, visible, controllable, with historical records for traceability
- Integrated single platform, unified management, fixed-mobile convergence, combining static and dynamic elements

Typical application scenarios:

Olefin tank farm / Chemical storage area / Refining and chemical units / Polymerization reactor area / Gas stations / LNG receiving terminal / Loading and unloading area / Long-distance pipeline high-consequence areas / Oil transfer stations / Oil storage depots / High and low voltage substations

3. Solution Value

Reduce personnel casualties and risks

- Replacement for high-risk positions
- Reducing inspection frequency
- Emergency site investigation

Reduce monitoring costs

- Extending inspection coverage area
- Reducing the required number of high-cost detectors to be deployed

Improve inspection quality

- Efficient problem identification
- Strict adherence to tasks
- Comprehensive inspection reporting

4. Results Showcase



05

Industrial Internet Big Data Platform Development

TRIP

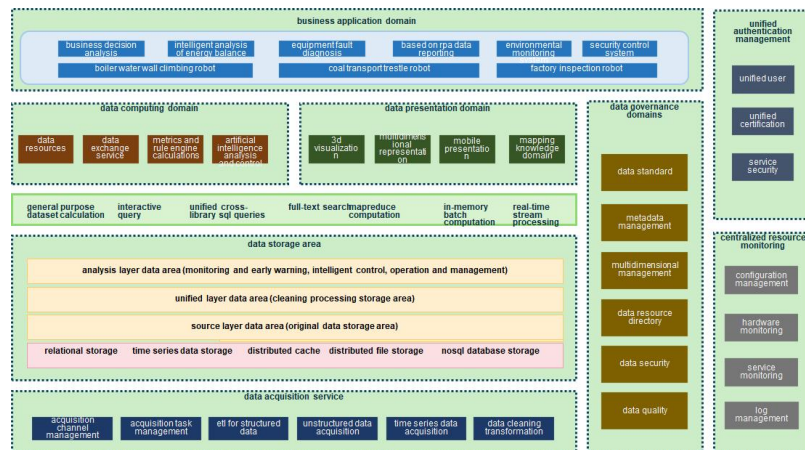
Industrial Internet Big Data Platform Development

1. Current Status

The development of smart energy is an inevitable trend in the information technology advancement of the energy industry. Establishing a unified big data platform for energy enterprises to centrally manage various types of generated data is a critical step in building smart energy solutions, as data assets have gradually become one of the core assets for enterprises. With the gradual enhancement of enterprise intelligence measures, various information systems and data volumes have grown exponentially, leading to common problems such as data redundancy, inconsistent data encoding, data fragmentation, and data idleness. These issues have prevented effective utilization of the massive enterprise data. To efficiently manage and utilize this data, the construction of an integrated big data platform tailored to the characteristics of the enterprise has become necessary. The platform will treat data as a valuable asset to be applied in core application scenarios such as equipment monitoring and early warning, equipment diagnostics, unit operation optimization, and enterprise decision support, bringing tremendous value to the energy enterprise's operations, production, runtime, safety, and environmental protection efforts.

2. Solution

The integrated data middle platform for energy enterprises is a smart infrastructure center that combines the collection, governance, storage, computing, and multi-dimensional visualization of enterprise production data and management data.



3. System Effects



4. Business Value

Establish unified data standards and data coding systems for coal, steel, petrochemical and other energy enterprises. Enterprises have a wide variety of units, equipment, sensors, materials, spare parts, and facilities with broad distribution ranges. The equipment management process involves a large amount of real-time data, inspection data, maintenance data, technical documentation, equipment drawings, and archives, among other data types. The big data platform can assist enterprises in establishing a unique identifier that spans the entire lifecycle of the power plant, associating the aforementioned equipment with data for unified management, facilitating accurate understanding and communication among professionals from different time periods, disciplines, and manufacturers.

Establish unified data governance standards, unified data storage mechanisms, and unified data models for energy enterprises. Formulate unified data collection strategies and data quality verification rules for different data models to ensure real-time, accurate, and unique data collection. This ensures efficient and secure unified storage of multi-source heterogeneous data, solving the current problem of data silos within enterprises.

Establish unified data service sharing capabilities to provide a foundation for data reuse across various business application modules in smart energy solutions. This reduces redundant data collection costs and cross-disciplinary communication and coordination costs, improving data usage efficiency.

Establish unified data computing, analysis, and mining models. Build a business indicator model center, an artificial intelligence model center, and a report display model center tailored to the characteristics of the enterprise. Once enterprise experts validate and confirm the analysis model results, they can be published to the three model centers for reuse across multiple business application systems, achieving the effect of building models once and reusing them repeatedly.



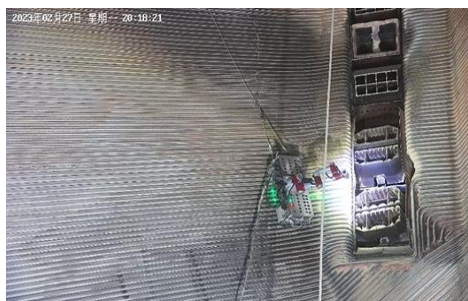
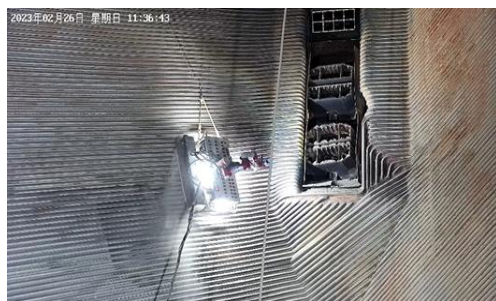
06 Typical Cases

Huaneng Group Laiwu Power Plant Water Wall Inspection Robot Project

Case Background: For the 1000MW ultra-supercritical unit at Huaneng Laiwu Power Plant, the water-cooled wall area has an elevation of 67.4 meters. The interior of the furnace has severe ash accumulation, making it impossible to directly observe wall tube defects due to the ash buildup. Traditional manual inspection required removing the ash accumulation, which was the biggest challenge, resulting in low efficiency, significant safety hazards, and poor reliability of inspection data.

Product (Module): Water-cooled wall inspection robot, visual defect detection, non-destructive thickness measurement module, roller ash removal module.

Problems Solved: For this project, as the unit uses dry ash removal and high-pressure water cannot be used for ash removal, a roller ash removal module was specially designed with a cleaning width of 600mm and an ash removal efficiency of 5.4 m²/min, effectively solving the issues of long ash removal times and incomplete cleaning faced by traditional methods at the power plant. The application of the inspection robot for maintenance work can standardize the inspection process, reduce personnel injuries, enhance early warning of potential hazards, and improve the efficiency of safe production management.

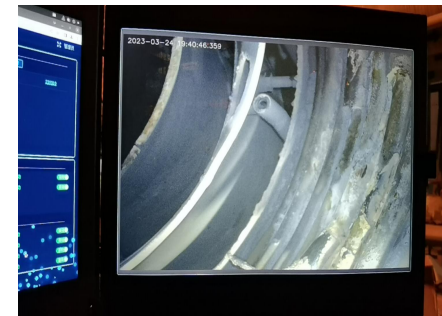
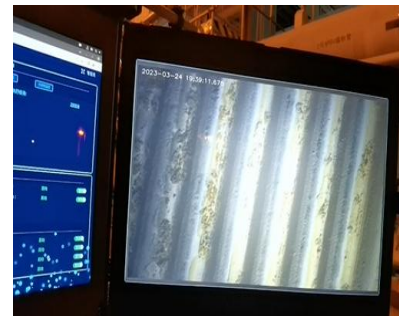
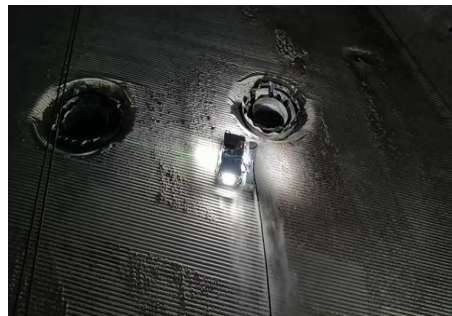
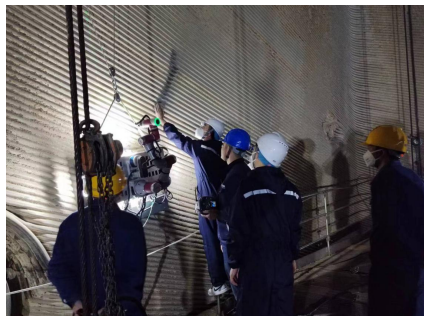
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Research and Application of Boiler Water Wall Inspection Robot at Zheneng Group Fengtai Power Plant

Case Background: Huaizheneng Fengtai Power Plant has two 600MW coal-fired steam turbine generator units. The interior of the furnace has severe ash accumulation. Currently, inspections are mainly conducted manually. During regular inspection operations, the deslaggers and burners are key inspection areas that require more time. The power plant hoped to complete inspections of all key areas without setting up elevated platforms.

Product (Module): Water-cooled wall inspection robot, roller ash removal module, non-destructive thickness measurement module, visual defect detection, third-party perspective inspection, deployment system.

Problems Solved: In this project, the inspection robot was equipped with a third-party perspective inspection module. Through flexible control of a 6-degree-of-freedom robotic arm, it could enter the interior of deslaggers or burners and complete visual inspections, saving about a week of inspection time compared to manual methods. This resolved the issue of excessive time required for inspecting key areas. Moreover, an innovative robot deployment system was developed to complete the robot deployment through a 500mm diameter manhole door, solving the problem of being unable to conduct high-altitude inspection work without setting up elevated platforms inside the furnace. This reduced the occurrence of missed inspections due to insufficient maintenance time, met the specific requirements for mandatory inspections during boiler shutdowns for anti-abrasion and anti-explosion measures, increased inspection frequency, improved inspection efficiency, and reduced inspection costs.



Intelligent Management and Control Platform for Ash Removal System at Datang Toqtog Power Plant

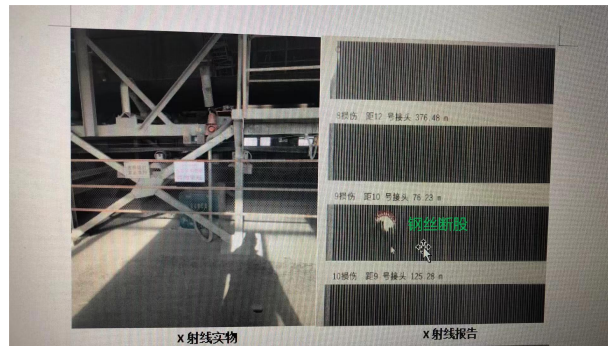
Project Name: Research on Key Technologies of Intelligent Inspection Robot for Long-Distance Ash Conveying Belt System at Inner Mongolia Datang International Toqtog Power Generation Co., Ltd.

Before Project Implementation:

During the ash removal process at Tuolunao, it was difficult for the ammonia gas residue from the denitration ammonia spraying mixed in the pulverized coal ash to dissipate. At the ash transfer points and in the enclosed galleries and rooms, the dust concentration was high, and the ammonia odor was severe, making it impossible for personnel to remain in the area for long periods to inspect the equipment operation. Additionally, with the belt conveyor extending over 4 kilometers, to ensure the normal operation of the conveying equipment, automated monitoring and robot inspections of key ash removal equipment were needed for the entire ash conveying gallery. Through big data, artificial intelligence, and other technologies, intelligent operation and maintenance of the ash conveying gallery could be achieved.

After Project Implementation:

The project has been accepted and is operating stably. Since the Tuolunao ash removal belt is 4 kilometers long, manual inspections took a long time and were difficult. Through the implementation of this project, advanced intelligent inspection robots, in coordination with intelligent sensors, were used to conduct real-time inspections of important equipment such as belt conveyors and pipe conveyors in harsh environments. Reliable and high-speed industrial control networks transmitted on-site signals to the server terminals in the control room for image recognition and big data analysis, forming a comprehensive equipment health diagnostic system platform. The Tuolunao Ash Removal Project's intelligent inspection platform can replace manual inspections of the pipe conveyor and its auxiliary equipment, realizing intelligent operation and maintenance of the ash conveying gallery. It provides early warning alarms, increases inspection frequency, reduces inspection time, and lowers safety and health risks, gradually achieving the goal of minimal to unmanned operations. Within one month after project implementation, a steel wire break in the conveyor belt was successfully detected. Upon inspection, a defect in the steel wire was found, avoiding a direct economic loss of 1.5 million yuan. Fortunately, the robot detected the incident in a timely manner, allowing maintenance personnel to take action and prevent further losses.



Research and Application of Coal Conveyor Gallery Inspection Robot at Shaanxi Yulin Energy Group Hengshan Coal and Power Co., Ltd.

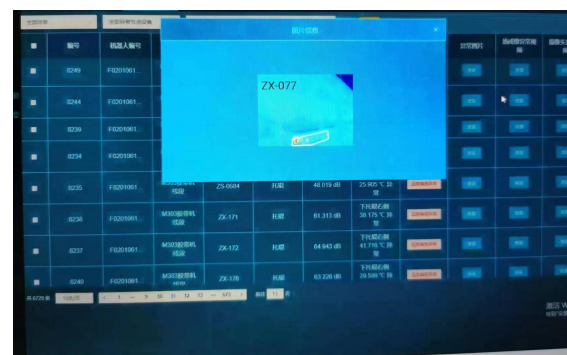
Project Name: Research and Application of Coal Conveying System Inspection Robot at Shaanxi Yulin Energy Group Hengshan Coal and Power Co., Ltd.

Before Project Implementation:

The coal conveyor galleries at coal-fired power plants are long with poor environmental conditions, and are high-risk areas for fires. The current manual patrol method used at most coal-fired power plants has issues such as high labor intensity, harsh working environments, and unstable inspection results. To achieve automated unmanned inspections of the coal conveyor galleries, an inspection robot platform was deployed in the No. 6 coal conveyor gallery to reduce manual input and improve work efficiency.

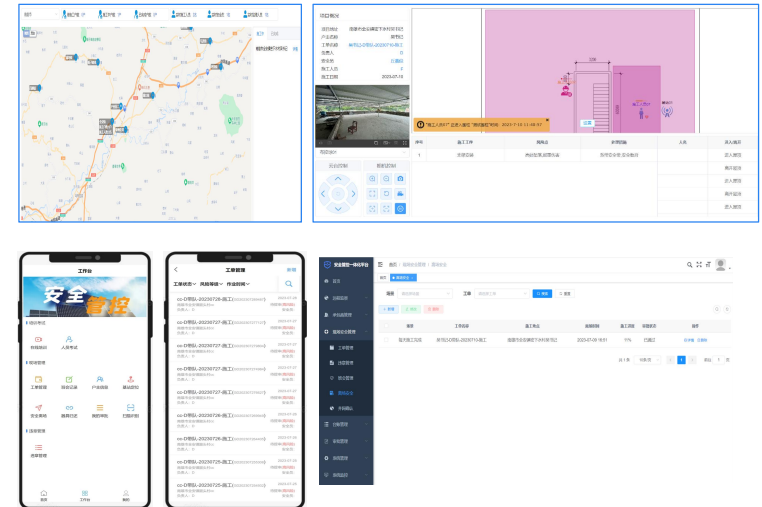
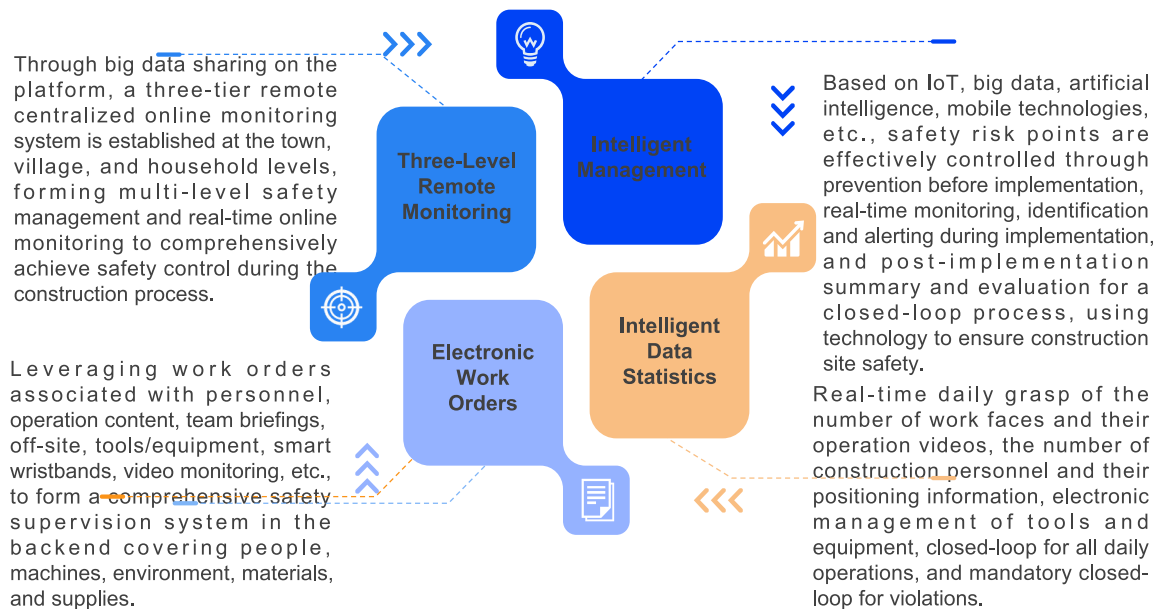
After Project Implementation:

The project has been accepted, and an intelligent operation and maintenance management platform has been deployed in the No. 6 coal conveyor gallery. The two belt conveyors, A and B, are configured with one operational and one backup. The robot can automatically identify which belt is running and conduct inspections according to pre-set items. Currently, it is operating well and can achieve intelligent inspections in the No. 6 coal conveyor gallery. Based on the current operation, it can save 4 person-times of manual inspection per day, freeing up 2 workers, while also reducing safety risks for operating personnel. In addition to saving labor, it enables efficient, comprehensive, and timely safety inspections of the entire coal conveyor gallery system. It can promptly detect on-site temperature, humidity, noise levels, dust concentration, and various toxic and harmful gases. The system also has fire and dust suppression interlock functions, enabling timely and effective detection and handling of abnormal situations.



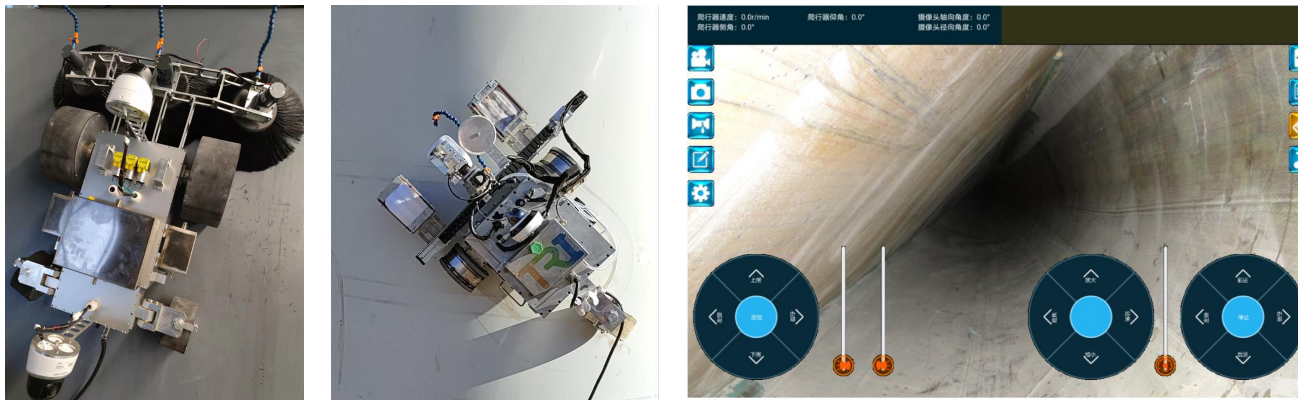
Intelligent Safety Management and Control Integrated Platform Project for Yuedian Zhuancun Wind Farm

Yuedian's intelligent safety management and control integrated platform for distributed photovoltaics utilizes current advanced "cloud, big data, IoT, mobile, and AI" technologies. It integrates the entire photovoltaic rooftop construction process with positioning base stations, PTZ cameras, law enforcement recorders, and smart wristbands. By comprehensively adopting personnel positioning, task work orders, team briefing management, electronic fencing, safety snapshots, and off-site safety measures, it achieves real-time monitoring and safety management of on-site operations. Additionally, it establishes a new intelligent integrated safety management system by implementing contractor and personnel qualification access control and safety training exams. The intelligent safety management and control integrated platform enables real-time rooftop personnel positioning through smart wristbands and achieves remote safety monitoring of on-site construction processes via smart PTZ cameras and law enforcement recorders. The platform enables comprehensive management and control of construction personnel, supervisors, safety officers, work faces, and operation content.



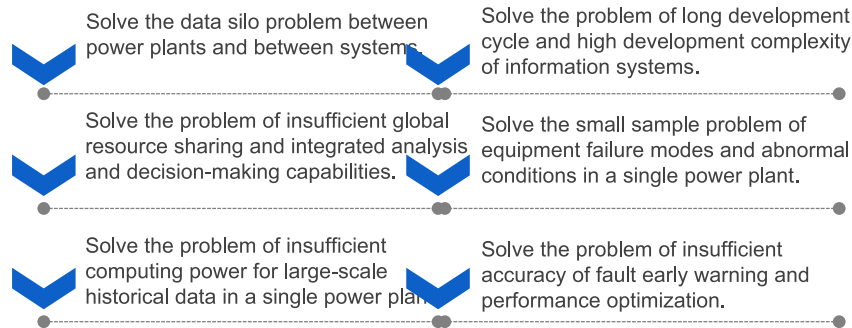
Application of Datang (Chifeng) New Energy Multi-functional Robot in Wind Turbine Tower Blade Inspection, Cleaning and Non-destructive Testing

Datang (Chifeng) New Energy Co., Ltd., a subsidiary of China Datang Corporation, is located in Chifeng City, Inner Mongolia Autonomous Region. It is responsible for the development, construction, production and operation of new energy projects such as wind power and solar power in the Chifeng area. As of now, the company has achieved a total installed capacity of 1.5103 million kilowatts, with 10 wind farms in operation and a total of 1,136 wind turbines of 14 models from 9 wind turbine manufacturers. The variety and quantity of wind turbines pose great challenges to the operation and maintenance management of the wind farms. In the long-term operation and maintenance of wind turbines, there are three challenges. First, for the oil leakage problem of doubly-fed units, oil leakage from the unit will cause pollution on the surface of the tower, which is unsightly and may cause a series of problems such as tower corrosion due to oil leakage. Second, the complexity of tower weld inspection. Generally, manual tower paint removal is required first, and then the weld is inspected by water coupling detection, which is very complicated. Third, it is difficult to inspect the inside of the blades. Inspectors need to enter the blade cavity for visual inspection. The inspection area is relatively small, and the inspection efficiency is low, and the inspection accuracy also has great uncertainty. The above operations need to be completed by working at heights, which has greater safety risks. In this project, two robots are developed. One is a tower cleaning and inspection robot, whose main work includes tower oil pollution cleaning and weld non-destructive testing, and it also has the ability of full-process high-definition real-time monitoring. The system includes the tower wall-climbing robot body, oil pollution cleaning module, tower weld flaw detection module based on TOFD instrument, high-definition camera monitoring module and other working modules, as well as the ground remote personnel control system. The other is a blade internal inspection robot, which travels in the space between the leading edge, trailing edge and web of the blade to detect defects such as voids, cracks, and splits in the bonding adhesive between the front and rear beams and the shell, as well as cracks, whitening, and wrinkles on the inner skin of the web and the cap of the middle main beam. It can reach more than 85% of the blade length into the blade cavity. After actual verification in the Saihan Wind Farm, the above two robots can well replace manual tower cleaning and inspection operations and blade internal inspection operations. It can bring great convenience to the operation and maintenance of wind turbines, reduce safety risks, improve work efficiency, improve inspection accuracy, and reduce inspection costs.

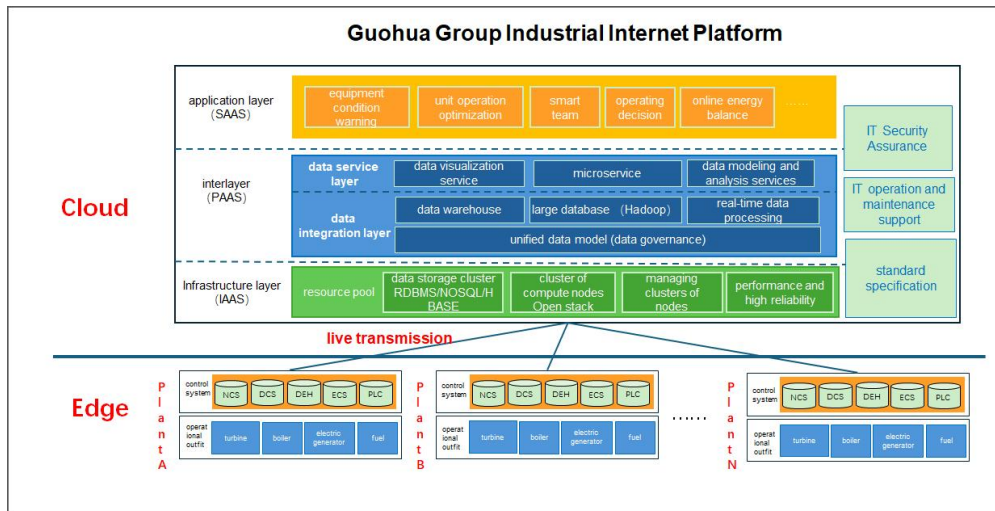


Beijing Guohua Electric Power Co., Ltd. Industrial Internet Platform

Before project implementation:



Solution:

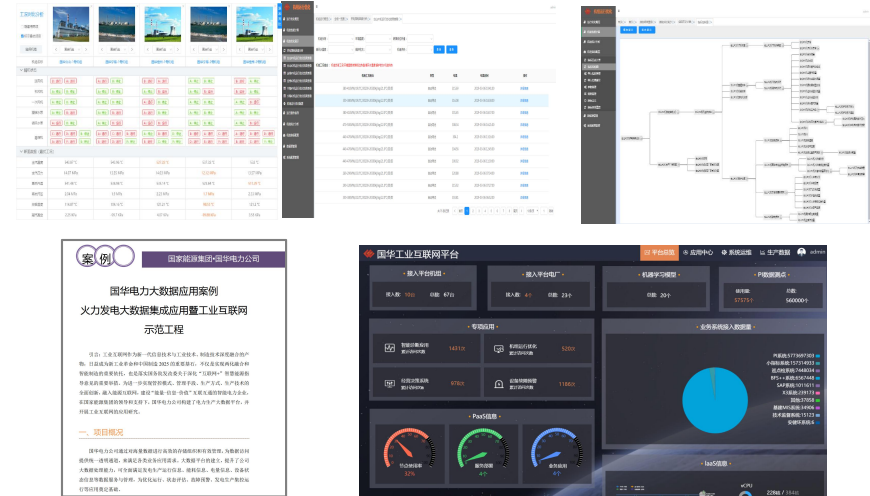


After project implementation:

The big data platform of Guohua Electric Power Company integrates big data analysis technology with the operation and maintenance management of thermal power plants, realizes rapid and flexible standardized development of business applications, collects data assets, innovates management models, promotes the formation of industrialized models of industrial technology/knowledge informatization, and lays the foundation for the industrial Internet platform architecture of Guohua Company, providing a good start for realizing the application ecosystem chain of smart enterprises.

Based on this solution, the company has created a platform system that integrates unified development, unified operation and maintenance, big data processing, and edge computing. It has realized the cloudification of enterprise IT infrastructure, centralized and unified analysis and utilization of data, and an innovative development model of "microservice" applications.

The platform has already accessed more than 100 billion real-time and near-real-time device sensor data, connected 10 coal-fired units in 4 power plants, deployed 14 services, 18 applications, and completed 20 types of machine learning models. Applications based on big data analysis, such as unit operation optimization and equipment fault early warning, have been deployed on the platform.



Other Cases

No.	Industry	Project Name	Customer Name	Signing Year
1	Thermal Power Plant	CP4 overhaul water wall AI robot inspection	Huayang Houshi Power Plant	2024
2		Water wall inspection robot	Guoneng Taishan Power Plant	2023
3		Water wall inspection robot	Guoneng Fugu Power Plant	2023
4		Water wall inspection robot	China National Nuclear Power Station Operation Service Technology Co., Ltd.	2023
5		Water wall inspection robot	Shanghai Electric Power Generation Equipment Complete Set Design Institute	2023
6		Water wall inspection robot	Huaneng Jinqiao Thermal Power	2023
7		Water wall inspection robot	Huadian Jurong Power Plant	2023
8		Water wall inspection robot	Huaneng Jinqiao Thermal Power	2023
9		Water wall inspection robot	Zheneng Fengtai Power Plant	2022
10		Water wall inspection robot	Huaneng Changxing Power Plant	2022
11		Water wall inspection robot	Huaneng Hegang Power Plant	2022
12		Water wall inspection robot	Guoneng Ninghai Power Plant	2022
13		Water wall inspection robot	Huaneng Laiwu Power Plant	2021
14		Water wall inspection robot	Datang Lubei Power Plant	2021
15		Water wall inspection robot	Guohua Dingzhou Power Plant	2020
16		Water wall inspection robot	Guoneng Jianbi Power Plant	2020

Other Cases

No.	Industry	Project Name	Customer Name	Signing Year
17	Thermal Power Plant	Water wall inspection robot	Datang Wangtan Power Plant	2020
18		Water wall inspection robot	Suzhou Thermal Engineering Research Institute Co., Ltd.	2020
18		Water wall inspection robot	Suzhou Thermal Engineering Research Institute Co., Ltd.	2020
19		Boiler four-pipe health analysis system	Guoneng Yuci Thermal Power	2023
20		Boiler four-pipe health analysis system	Huaneng Ruijin Power Plant	2022
21		Boiler four-pipe health analysis system	Guoneng Jiujiang Power Plant	2022
22		Boiler four-pipe health analysis system	Datang Yangcheng Power Plant	2022
23		Boiler four-pipe health analysis system	China Datang Corporation Science and Technology Research Institute Co., Ltd. Wushashan Power Plant	2021
24		Boiler four-pipe health analysis system	Guoneng (Quanzhou) Thermal Power Co., Ltd.	2021
25		Coal conveying corridor inspection robot	Shaanxi Coal Huangling Power Plant	2023
26		Coal conveying corridor inspection robot	Xinhui Shuangshui Power Plant	2023
27		Coal conveying corridor inspection robot	Datang Faer Power Plant	2023
28		Coal conveying corridor inspection robot	Yuneng Hengshan Coal Power	2022
29		Coal conveying corridor inspection robot	Hangzhou Shenhao Technology Co., Ltd.	2022
30		Coal conveying corridor inspection robot	Datang Lvsigang Power Plant	2022
31		Coal conveying corridor inspection robot	Zhun Neng Group Haerwusu Coal Preparation Plant	2022
32		Coal conveying corridor inspection robot	Datang Tuoketuo Power Plant	2021
33		Coal conveying corridor inspection robot	Huaneng Helin Power Plant	2020
34		Intelligent safety control integrated platform system	PowerChina Guangdong Thermal Power	2023

Other Cases

No.	Industry	Project Name	Customer Name	Signing Year
35	Thermal Power Plant	Condensate polishing regeneration system automation upgrade	Datang Jixi Thermal Power	2022
36		Data middle platform - terminal AI algorithm platform	Huaneng Ruijin Power Plant	2022
37		Intelligent inspection robot application research on belt conveyors	Datang Xilinhote Power Plant	2022
38		Air cooling island big data mining cleaning robot	Datang Yungang Thermal Power	2022
39		Data middle platform - terminal AI algorithm platform	Huaneng Ruijin Power Plant	2022
40		Smart operation management system	Guoneng Taishan Power Plant	2021
41		Integrated smart production control platform	Yuneng Hengshan Coal Power	2021
42		Smart safety system	North Weijiyao Power Plant	2021
43		Integrated smart production control platform (two-ticket control, defect control, inspection control)	Yuneng Hengshan Power Plant	2021
44		Power generation equipment condition maintenance - rotating machine vibration data acquisition and analysis system development	Huaneng Dalian Thermal Power	2021
45		Industrial Internet platform	Guohua Electric Power Corporation Headquarters	2020
46		Smart power plant construction project	Guohua Sanhe Power Plant	2018
47		Ultra-intelligent power station construction project	Guohua Electric Power Corporation	2017

Other Cases

TRI Energy Industry Application Cases (Partial)				
No.	Industry	Project Name	Customer Name	Signing Year
1	Wind Power	Wind turbine tower cleaning and inspection robot	Guoneng Jishangliang Wind Farm	2023
2		Wind turbine tower cleaning and inspection robot	Guodiantou Qianzhan Wind Farm	2023
3		Wind turbine tower cleaning and inspection robot	Huaneng Shaanxi Jingbian Power Plant	2023
4		Wind turbine tower cleaning and inspection robot	Datang Chifeng Wind Farm	2021
5		Wind turbine nacelle inspection robot	Yuedian Yangjiang Wind Power	2022
6		Wind turbine nacelle inspection robot	Yuedian Dibai Reshui Wind Farm	2022
7		Blade repair drilling robot	Ming Yang Wind Power	2020
8		Intelligent inspection system development	Yuedian Pingyuan Wind Farm	2023
9		Intelligent safety control integrated platform	Yuedian Nanxiong Wind Farm	2023
10		Wheeled robot & rail robot	PowerChina Barkol Wind Farm	2023
1	Coal/ Petrochemical/ Steel and Other Fields	Belt unmanned inspection project	Jingye Steel	2024
2		Wheeled inspection robot	Tai'an Steel Plant	2023
3		Wheeled inspection robot	Jingye Steel	2023
4		Indicator management platform software	Yanchang Fuxian Power Plant	2023
5		M14, M33 coal conveying belt track robot system	Jun Energy Haerwusu Coal Preparation Plant	2022
6		M303 coal conveying belt track robot system	Jun Energy Haerwusu Coal Preparation Plant	2022
7		Coal conveying corridor inspection robot	Zhenhai Refining & Chemical	2022
8		Coal mine gas risk assessment system software development	Emergency Management Department Information Research Institute	2022
9		Gas monitoring and early warning system development and implementation	Zhongan Zhixun (Beijing) Information Technology Co., Ltd.	2022
10		Remote monitoring big data platform	National Coal Mine Safety Supervision Bureau	2020
11		Coal yard smart safety management project	Hebei Fukuan Electromechanical Technology Co., Ltd.	2021



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