White Paper：

Distributed Optical Fiber Intelligent Integrated Solution for Medium and High Voltage Cables

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Compilation Notes

1. This white paper is compiled based on China’s 15th Five-Year Plan for new power infrastructure investment, global energy transition industrial data and IEC international cable monitoring standards. It fully covers the complete technical principles, implementation values, engineering cases and corporate global development strategies of DTS Distributed Optical Fiber Temperature Sensing and DAS Distributed Optical Fiber Acoustic Vibration Sensing.

2. Centered on promoting built-in optical fiber intelligent cable products, this document targets customers in power grids, data centers, high-end manufacturing, offshore wind power and rail transit, while building the industrial technical brand influence of ADAT power.

3. All quantitative indicators and project data in this document are derived from actual power grid projects and authoritative industrial white papers, making it formally applicable for bidding, technical exchanges and business presentations.

1 Industry Insight: The Contemporary Challenges of Medium & High-Voltage Cable Operation & Maintenance

1.1 Trillion-Level Policy & Market Dividends Usher in a Rapid Growth Period for Intelligent Cables

1.1.1 Strong Driven by Top-Level National Policies

1. China’s 15th Five-Year Plan for New Power Grid Infrastructure has a total planned investment of RMB 5 trillion, among which State Grid Corporation of China alone plans an investment of RMB 4 trillion. Comprehensive upgrades of ultra-high voltage (UHV) power grids and urban distribution networks are in full swing, triggering rigid demand for intelligent sensing cables and online monitoring equipment.

2. The Ministry of Industry and Information Technology has set mandatory digital transformation assessment targets for manufacturing industries: the numerical control rate of key production processes of manufacturing enterprises shall exceed 75% by 2027, and the penetration rate of digital R&D tools shall surpass 90%. Power cables are required to be equipped with built-in status sensing modules, phasing out traditional "dumb cables" without monitoring functions.

1.1.2 Expanding Domestic & Overseas Market Scale

1. Global Market: The compound annual growth rate (CAGR) of global intelligent cables reaches 18%, with the market size exceeding USD 15 billion in 2025. Grid renovation in Europe and America, industrial infrastructure construction in Southeast Asia, and offshore wind power projects continuously generate new market demand.

2. Domestic Market: The overall market size of industrial monitoring cables in China will hit RMB 48.5 billion in 2026. The market scale of the optical fiber sensing segment will exceed USD 3.5 billion by 2030. Boosted by the East Data West Computing initiative and the construction of computing data centers, high-end monitoring cables are embracing a window of structural growth.

1.2 Four Critical Pain Points of Traditional Cable O&M

Pain Point 1: Huge Economic Losses Caused by Power Outages from Cable Failures

Most cable lines have reached or exceeded their 30-year design service life. Insulation aging, overheated joints, and external construction damage lead to frequent faults. Industry statistics show that the average economic loss per hour of power outage due to a single cable fault is RMB 127,000, and outage losses in industrial parks and data centers surge exponentially.

Pain Point 2: Passive O&M Mode Without Early Warning Mechanisms

Traditional O&M relies on post-fault emergency repairs, lacking full-line real-time sensing capabilities. Hidden hazards such as insulation degradation, local overheating, and excavation construction cannot be identified in advance. Minor defects keep deteriorating and eventually trigger major accidents including large-scale power outages and fires.

Pain Point 3: Overloaded Manual Inspection with Massive Blind Spots

Traditional grid-style manual inspection suffers from extremely low efficiency; on average, one maintenance staff can only take charge of 40 kilometers of cable lines. As the scale of urban underground pipe networks and tunnel-laid cables keeps expanding, manpower cannot achieve full coverage, resulting in severe delays in hidden danger troubleshooting.

Pain Point 4: Dual Internal & External Safety Risks – 81% of Failures Stem from External Damage

Industry fault statistics indicate that 81% of cable failures are caused by external construction such as reckless excavation and mechanical impact. Internal hidden risks including insulation aging and

overheated joints exist over the long term. The superposition of internal and external hazards creates enormous difficulties in safety management of underground cables.

2 Solution: Integrated Intelligent Cable System with DTS & DAS

2.1 Core Architecture: Integrated Dual-Optical-Fiber Sensing Design with Dual Detection in One Cable

Abandoning the retrofitting scheme of traditional external sensors, this solution integrates Distributed Optical Fiber Temperature Sensing (DTS) and Distributed Optical Fiber Acoustic Vibration Sensing (DAS) into a single composite sensing optical cable pre-embedded during cable manufacturing. No dedicated monitoring pipelines need to be laid additionally. It synchronously collects full-line temperature distribution and mechanical vibration signals to realize dual omnidirectional sensing via one cable.

2.2 Three-Tier System Operation Framework

Tier 1: Full-Coverage Millisecond-Level Sensing Network Without Blind Spots

Leveraging the continuous distributed physical characteristics of optical fibers, a monitoring network covering the entire life cycle of cables is constructed. It achieves meter-level spatial resolution and millisecond-level data refresh. Adaptable to complex operating conditions such as underground pipelines, tunnels and seabeds, the system instantly captures all abnormal signals including overheating, insulation defects and external disturbances.

Tier 2: Edge-Cloud Collaborative AI Intelligent O&M Engine

Lightweight edge computing units are matched with cables to preprocess raw on-site data locally without full backhaul to the cloud. Real-time waveform and temperature data are compared with the built-in fault feature library via AI to output risk warnings within milliseconds. Linked with the cloud expert diagnosis system, the platform automatically generates fault location and disposal work orders, forming a full closed-loop unmanned O&M workflow: Data Perception → Intelligent Analysis → Automatic Decision-Making → Closed-Loop Execution.

Tier 3: Four-Dimensional Composite Intelligent Cable Body (Core Hardware)

A four-layer composite structure is integrally formed during production: Power Transmission Conductor + Multi-Layer Insulation + Built-In Sensing Optical Fiber + High-Strength Outer Sheath. The cable evolves from a single power transmission carrier to a distributed intelligent sensing terminal, realizing dual functions of power transmission and self-inspection simultaneously.

1. Power Transmission Layer: High-purity conductors and cross-linked multi-layer insulation enable stable long-distance power transmission with low loss.

2. Sensing Layer: Special built-in sensing optical fibers act as the "neural network" of cables,

continuously collecting real-time temperature and vibration data along the entire line.

2.3 DTS Distributed Optical Fiber Temperature Sensing Technology – The Full-Line "CT Thermometer" for Cables

2.3.1 Working Principle

Based on the Raman scattering effect of optical fibers, the system obtains precise temperature values at every point of the fiber by comparing the light intensity ratio of Stokes light and anti-Stokes light combined with Optical Time Domain Reflectometry (OTDR). It realizes continuous uninterrupted temperature measurement of the entire cable, breaking the limitations of traditional single-point temperature measurement.

2.3.2 Core Technical Indicators

1. Temperature measurement accuracy: ±0.5℃; temperature resolution: 0.1℃

2. Spatial positioning accuracy: 0.5 meters

3. Operation mode: 7×24-hour uninterrupted millisecond-level data update

2.3.3 Four Core Functions

1. Active early warning of local overheating: Identify temperature rise at joints and cables in advance to avoid insulation breakdown.

2. Dynamic line capacity increase: Tap safe current-carrying capacity based on real-time temperature data and delay investment in grid expansion.

3. Ultra-early fire detection in tunnels: Capture temperature rise precursors hours earlier than traditional smoke detectors.

4. Precise fault location: Lock overheating points with 0.5-meter accuracy and greatly shorten troubleshooting time for emergency repairs.

2.4 DAS Distributed Optical Fiber Acoustic Vibration Sensing – The Distributed "Stethoscope" for Cables

2.4.1 Working Principle

Based on coherent Rayleigh scattering and phase-sensitive Φ-OTDR technology, the system demodulates tiny phase deformation of optical fibers, converts sub-nanometer vibration and sound waves into digital signals, and restores all dynamic disturbances along cables.

2.4.2 Core Technical Indicators

1. Sensing sensitivity: Capture sub-nanometer micro-deformation

2. AI event recognition accuracy: ≥95%

3. Hidden danger positioning error: ≤10 meters

4. Full-band signal coverage: Collect complete spectrum from infrasound to ultrasound

2.4.3 Five Core Application Functions

1. Anti-external-damage monitoring for third-party construction: Real-time identification of excavation and impact, issuing pre-alarms to prevent faults.

2. Partial discharge diagnosis of cable joints: Capture ultrasonic signals generated by damaged insulation.

3. Long-term structural deformation monitoring for tunnels, bridges and dams.

4. Abnormality identification of exposed submarine cables and seabed scouring.

5. Automatic hierarchical push of risks for all scenarios and all weather conditions.

2.5 Upgrade of Solution Paradigm: From Passive Emergency Repair to Active Immunity

Traditional O&M Mode: Regular manual inspection + post-fault emergency repair, featuring severe lag and uncontrollable losses. Andian Tong DTS+DAS Integrated Intelligent Cable: 7×24-hour full-line online monitoring + AI early intervention. The safety control threshold is moved forward, fault response efficiency is improved by over 80%, and long-term O&M costs are greatly reduced.

3 Value Proposition: Comprehensive Improvement in Safety, Efficiency and Cost Control

3.1 Value 1: Active Safety Defense to Eliminate Major Power Outage Accidents

1. 85% reduction in fault occurrence rate: Early warnings block the evolution of hidden dangers and reduce unexpected shutdowns at the source.

2. 30% drop in external damage faults: Verified by practical projects of Huadu Power Supply Bureau, Guangzhou.

3. Mean Time To Repair (MTTR) shortened from 8 hours to 2.5 hours for rapid power restoration.

4. Ultra-early fire warning reserves sufficient golden time for evacuation and rescue.

3.2 Value 2: Digital Transformation of O&M Mode with Exponentially Improved Manpower Efficiency

1. 60%-70% reduction in on-site manual inspection frequency; a large number of field patrols are replaced by online monitoring.

2. 80% reduction in offline power-off preventive tests, eliminating production and computing losses caused by power cuts.

3. Upgraded O&M strategy: Fixed-cycle blind patrol → Targeted inspection based on equipment status.

4. Manpower optimization: O&M staff for every 100 kilometers of cables cut from 6 to 2 persons.

3.3 Value 3: Significant Optimization of Asset Life Cycle Cost (LCC)

Short-Term Benefits (Visible in the First Year of Renovation)

1. 35%-45% annual savings on manual O&M costs.

2. 60% reduction in hidden losses from emergency repairs and production shutdowns.

3. 42% drop in total O&M costs in the first year after intelligent renovation.

4. Static investment payback period of the project: only 2.8 years.

Long-Term Full-Life-Cycle Benefits Over 20–25 Years

1. Predictive maintenance slows cable aging and extends cable service life by 15%-25%.

2. Cumulative cost savings of RMB 18.5 million for high-voltage cable systems in large airports and data centers within 25 years.

3. Reduced continuous investment in spare parts procurement and major overhauls.

3.4 Exclusive Value for New Scenarios: Data Centers & High-End Manufacturing

Customized value for medium and high-voltage power supply cables in computing hubs, semiconductor wafer fabs and high-end equipment industrial parks:

1. Full-range temperature measurement of high-voltage incoming cables to avoid overheating shutdown of high-density cabinets.

2. Real-time identification of vibration transmission damage to precision equipment to protect cable insulation.

3. Full-process online monitoring without shutdown of production lines and servers, achieving zero production suspension monitoring cost.

4 Practical Verification: In-Depth Analysis of Benchmark Projects at Home and Abroad

4.1 Domestic Power Grid Benchmark Cases

Case 1: Wudongde UHV DC Demonstration Project of State Grid

This national cross-regional long-distance power transmission project deploys large-scale DTS/DAS integrated intelligent cables along the entire line. Full-line real-time monitoring of temperature and external damage is realized via full optical fiber sensing. More than 1,000 sets of intelligent monitoring systems have been delivered in total, solving the problem of inspection blind spots in complex UHV terrain and providing a standardized digital monitoring scheme for national UHV projects.

Case 2: Anti-External-Damage System of a Power Supply Bureau under China Southern Power Grid, Guangzhou

A DAS distributed acoustic vibration protection network is built with AI automatic identification of mechanical excavation and illegal construction. Project achievements:

1. Over 40 hidden construction damage hazards intercepted successfully every year.
2. Year-on-year 30% reduction in external damage faults.
3. RMB 5 million annual savings on emergency repair costs.
4. AI event recognition accuracy ≥95%, hidden danger positioning accuracy ≤10 meters.

4.2 Overseas Benchmark Projects

Case 1: Submarine High-Voltage Cables for European Offshore Wind Power

Adapted to marine high-salinity and complex hydrological environments, DTS monitors temperature rise caused by seabed scouring while DAS captures vibration from anchor machinery and ship dragging. The system automatically identifies risks of exposed cables and insufficient burial depth, suitable for long-distance submarine pipelines of offshore wind farms.

Case 2: Cross-Border Long-Distance Oil & Gas Pipelines in North America

DAS monitors excavation construction along the pipeline, and DTS captures abnormal temperature caused by pipeline leakage. The distributed optical fiber solution features zero electromagnetic interference, suitable for all-weather unmanned pipeline monitoring in the wild, and has become the mainstream protection solution for global energy enterprises.

4.3 Summary of Adaptability to Complex Extreme Environments

The dual-mode integrated DTS+DAS technology can operate stably in cable tunnels, cross-sea pipelines, factories with strong electromagnetic interference and underground comprehensive pipe galleries, overcoming engineering pain points such as heavy noise, signal attenuation and narrow space. Renovation construction does not require full-line power outages, applicable to two scenarios: upgrading existing cables and matching new cables.

4.4 Summary of Unified Quantified Project Achievements

1. Fault positioning accuracy improved to ±0.1~±0.4 meters, with a high-precision version reaching 0.05 meters.
2. Hidden danger warning response speed increased by 500%.
3. Overall system false alarm rate reduced by 92%.
4. Zero major safety accidents achievable in all application scenarios.

5 Strategic Suggestions: Empower Andian Tong to Lead Industrial Digital Upgrade

5.1 Differentiated Corporate Strategic Positioning

Build a global integrated comprehensive solution provider integrating intelligent medium & high-voltage cables and AI cloud O&M platforms. Link the company's self-owned primary equipment including switchgears and ring main units, open underlying protocols for sensing data and power distribution control, realize full closed-loop of cable sensing and switch execution, and build irreplicable software & hardware integrated technical barriers among competitors.

5.2 Three Core Development Directions

5.2.1 Independent & Controllable Core Technologies

Continue to increase R&D investment in optical fiber sensing and edge AI algorithms, break through underlying technologies including optical fiber demodulation and multi-signal fusion, build a fully independent software and hardware foundation, get rid of dependence on overseas core components and algorithms, and guarantee information security of power infrastructure.

5.2.2 In-Depth Customization for Industrial Scenarios

Abandon the general standardized product mindset. Develop exclusive intelligent cables and O&M platforms for five major scenarios: urban distribution networks, UHV power grids, offshore wind power, data centers and rail transit, catering to the real O&M pain points of frontline staff in various industries.

5.2.3 Co-Building the Full Industrial Chain Ecosystem

Cooperate with upstream and downstream enterprises including cable raw material suppliers, sensing equipment manufacturers, power grid integrators and digital platform providers, jointly formulate unified industry data interconnection standards, promote the compilation of industrial specifications for distributed optical fiber monitoring, and collaboratively reduce the overall project implementation cost.

Appendix Summary Table of Core Data

Index Name	Value	Data Source
CAGR of Global Intelligent Cables	18%	Global Energy Equipment Research Institute
Total National Power Grid Investment under the 15th Five-Year Plan	RMB 5 Trillion	New Power Grid Planning Document, National Development and Reform Commission

DTS Temperature Measurement Accuracy	±0.5℃	Industrial Optical Fiber Sensing Product Technical Manual
O&M Cost Reduction in the First Year of Intelligent Renovation	42%	Actual Urban Distribution Network Renovation Projects in China
Static Investment Payback Period of Projects	2.8 Years	Full Life Cycle Cost Calculation Model
Annual Emergency Repair Cost Savings in Guangzhou	RMB 5 Million	Annual Report of China Southern Power Grid Projects
AI Event Recognition Accuracy of DAS	≥95%	Actual Power Optical Fiber Monitoring Projects
Reduction Range of Manual Inspection Frequency	60%-70%	Cable Intelligent Renovation Case in Shanghai
Average Hourly Power Outage Loss per Cable Fault	RMB 127,000	White Paper on National Cable Operation & Maintenance Faults

Notes for Standardized Terminology

DTS: Distributed Optical Fiber Temperature Sensing

DAS: Distributed Optical Fiber Acoustic Vibration Sensing

OTDR: Optical Time Domain Reflectometry

MTTR: Mean Time To Repair

LCC: Life Cycle Cost

UHV: Ultra-High Voltage

CAGR: Compound Annual Growth Rate

Φ-OTDR: Phase-Sensitive Optical Time Domain Reflectometry