Effect factors of sandstorm on insulator and hardware damage of power transmissions in deserts

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NARI

Company Overview

Wuhan NARI Limited Liability Company of State Grid Electric Power Research Institute (hereinafter referred to as "Wuhan NARI"), as the wholly-owned subsidiary of NARI Group (State Grid Electric Power Research Institute), is a high-tech enterprise specializing in R&D, design, manufacturing and engineering services of smart grid power transmission related products. The business scope of Wuhan NARI covers four major areas: smart grid operation and maintenance products and services, new electrical materials, energy saving engineering and services, and smart electrical equipment. The company has the capacity to construct power transmission and distribution networks, new energy engineering projects and laboratory engineering projects as engineering-procurement-construction (EPC) contractor.

Wuhan NARI is becoming an active player in the global market. In recent years, the company has undertaken engineering and technical services projects in South American and Asian countries such as Ecuador, Malaysia, etc. The major products have successfully entered the Asian and African markets. In 2013, the first oversea subsidiary of NARI - NARI Brazil Holding Ltda. was set up under the co-investment of NARI Group and Wuhan NARI, signifying a first step of establishing worldwide manufacturing bases.

Located in the Wuhan East Lake High-tech Zone, Wuhan NARI is the industrial base of NARI Group in the city of Wuhan. With a total asset of nearly RMB 2.5 billion and more than 1,100 employees, the company now has four subsidiaries: NARI New Electrical Materials Company, Xiangyang State Grid Composite Insulator Co., Ltd. NARI-GE Intelligent Monitoring and Diagnosis (Wuhan) Co., Ltd, and NARI Wuhan Electric Engineering Company. which are respectively located in Wuhan and Xiangyang, etc. in Hubei Province.

Product Application

Smart Grid Operation And Maintenance Products And Services

- Condition monitoring and maintenance
- Lightning Detection and Protection
- High Voltage Test and Metering

New Electrical Materials

- New Electrical Materials
- Nano-modification materials;
- Vegetable-based insulating oil;
- Cable accessories;
- Line lightning arrester;
- Composite insulator.

Energy Saving Engineering And Services

- Energy saving engineering and services

Smart Electrical Equipment

- Switch equipment
- Combined electric appliance
- Preassemble type intelligent substation

Engineering-Procurement Construction (epc) Contractor

- Power transmission and distribution networks construction
- New energy engineering

Product Application

Condition monitoring and maintenance

The Operation& Maintenance products for transmission lines effectively secure normal operation of power transmission equipment and improve the reliability of power supply, providing an important technical support for the security and stability of the electrical grid.

Key Product Series:

- Intelligent substation condition monitoring and diagnosis system
- Online monitoring devices of transmission line and master station system
- Condition monitoring and fault diagnosis system of transmission line
- Intelligent mobile patrol auxiliary system of transmission line;
- Intelligent components of transformers;
- Gas-insulated switchgear (GIS) and intelligent components of circuit breakers;
- Intelligent components of capacitive devices;
- Laboratory vehicles for condition maintenance;
- 3D-visible operation management platform of transmission line;
- Training system for high voltage test simulations of substation equipment;
- Training system for fault diagnosis simulations of substation equipment;
- Training system for live wire operation simulations;
- Training system for operation maintenance simulations;
- Calibration and verification device series.

Intelligent components of transformers

Diagnose and service life evaluation system of transformer

3D-visible operation management platform of transmission line

Training system for live wire operation simulations

Lightning Detection and Protection

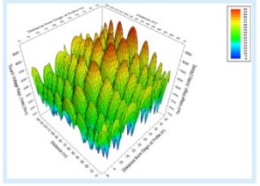
Aiming at fundamental, crucial, front-line and practical issues in the field of lightning protection and grounding technologies, based on a solid and mature foundation of lightning detection platforms, lightning protection technologies, grounding technologies and early warning systems, Wuhan NARI develops comprehensive technological and administrative strategies for lightning protection of electrical grids, and provides total solutions as well as product series for diverse areas and branches, including transmission and distribution lines, power plants and substations, petrochemical industry, rail systems, photovoltaic and wind power systems, etc.

Key Product Series:

- Lightning monitoring and warning system;
- Direct lightning protection products;
- Lightning protection products for distribution network;
- Second lightning protection products;
- Grounding products;
- Lightning protection and consulting service for grounding technologies.

220KV/500KV line arrester

lightning Dectecting Station



lgntning parameters statistics

lightning information system

Product Application

High Voltage Test and Metering

Wuhan NARI develops instruments for test, calibration and verification of electrical measuring equipment, which can be applied to 6 KV ~ 750 KV current/voltage transformers. High voltage test equipment are developed to serve power failure and live-line testing of power generation and supply systems and thus to secure the operation of a strong smart grid. The development of special vehicles for power generation combines the remodeling of professional motor vehicles with field test and application of detection instruments on vehicles, as well as equipping with auxiliary test and security systems, so a flexible, mobile, safe and efficient solution for routine test and emergency repairs can be provided.

Key Product Series:

- Measurement and test equipment: Automatic verification system with low voltage current transformer, mutual inductor field and laboratory test devices and online monitoring system for electric energy metering devices;
- Training devices for simulations of 3D quantization and measurement;
- High voltage testing equipment: high voltage AC/DC current testing equipment and measuring instrument;
- Special vehicles by power generation: High voltage test vehicles, location metrology vehicles with power transformer, online inspection vehicle, electric energy metering vehicles, measurement vehicles for power distribution, etc.

Location metrology vehicles with power Transformer, online inspection vehicle

Special vehicles by power generation: High voltage test vehicles

Measurement and test equipment: Automatic verification system with low voltage current transformer

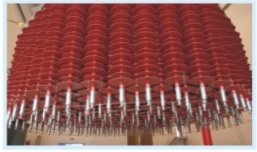
New Electrical Materials

Wuhan NARI independently develops products including 10 KV ~ 220 KV composite material poles and towers (cross arm), anti-pollution flashover coating (RTV/PRTV), cable accessories and composite insulators etc., which have been widely used in power industry, electronics industry, communication systems, rail traffic and petrochemical industry and other fields. New products such as vegetable-based transformer oil and ±500 KV DC surge arrester have succeeded in trial network operations. Exemplars of carbon nanotubes (CNTs) modified aluminum alloy materials, including high strength aluminum alloy stranded conductor, high conductivity all-aluminum conductor and bus bar with high strength and conductivity, etc., have achieved the goals of performance.

Key Product Series:

- Composite material poles and towers (cross arm);
- Nano-modification materials;
- Novel coating materials;
- Vegetable-based insulating oil;
- Cable accessories;
- Line lightning arrester;
- Composite insulator.

Composite material poles and towers (cross arm)



Composite insulator

Cable accessories

Product Application

Energy Saving Engineering and Service

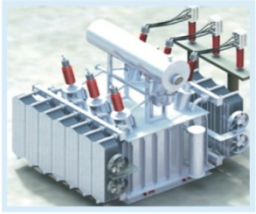
The company has technical advantage in providing total packaging services for diverse forms of energy performance contracting and energy conservation projects (including photovoltaic power station projects). Enterprises can be provided with comprehensive energy saving assessment and analysis as well as technical solutions for energy saving operation and rebuilding, so they are assisted to explore their energy saving potential, enhance their energy utilization efficiency, reduce their energy consumption, realize energy conservation and emission reduction, and thus continuously enhance economic performance of the enterprise.

Key Product Series

- Comprehensive energy efficiency management system for enterprise /industrial park;
- Online monitoring and loss reduction navigation system for line loss;
- Electricity saving appliance in power distribution system;
- Magnetic controllable reactor;
- Novel battery energy storage system.

Low-voltage electricity saving appliance

High-voltage electricity saving appliance



Novel battery energy storage system

Magnetic controllable reactor;

Smart Electrical Equipment

The product range of smart electrical equipment covers complete sets of equipment of high-, medium- and low-voltage power transmission and distribution, and high- and low-voltage switching elements. Wuhan NARI has developed the vacuum circuit breaker with automatic phase selector switch. Within the frame of the trend of intelligent electrical equipment and national guiding policies for the equipment manufacturing industry, Wuhan NARI considers the product intelligentization and system integration as the entry point and actively develops the business of pre-installed smart transformer substations.

Key Product Series

- High-voltage outdoor and indoor vacuum circuit breaker;
- Intelligent phase selection breaker;
- High- and low-voltage switch cabinet;
- Solid insulation ring main unit;
- Low-voltage distribution compensated chamber;
- 35KV~220KV pre-installed smart transformer substation.

New-generation circuit breaker

Equipment set

Preassemble Intelligent Substattion

Product Application

EPC Construction of Power Transmission & Distribution Networks

By virtue of years of research and engineering practice in the field of power transmission and distribution, by giving full play to the rich experience and technological strength of the numerous power system experts, Wuhan NARI provides planning, consultation and EPC contracting services for power transmission and distribution projects, and is capable to develop comprehensive solutions for customers to build a robust, reliable and intelligent power supply and distribution system.

EPC Construction of New Energy Projects

Wuhan NARI has conducted many researches in the field of photovoltaic power generation and gathered enormous data as well as practical experience. Staffed with an experienced strong team of senior experts and professional project managers, Wuhan NARI has successfully accomplished various photovoltaic power generation projects. The company provides customers with technology consulting, scheme design and project application for photovoltaic on- and off-grid and intelligent micro-grid power generation technologies, and acts as EPC contractor for photovoltaic power generation projects.

1 2 3

1 Wuhan future city smart grid EPC construction

2 50MW grid integration photovoltaic power generation EPC

3 China State Grid Ocean power transmission experiment base

EPC Construction of Lab Engineering Projects

Wuhan NARI has gained rich large-scale project management experience in the constructions of ultra-high-voltage alternating current (UHVAC) bases, UHVAC demonstration projects and cable labs etc. The transformer testing lab, high-voltage measurement lab, cable lab and electromagnetic compatibility lab which are independently designed by Wuhan NARI have performed well in AC/DC tests and routine tests at 1000kV and below. Wuhan NARI has gathered much experience in lab construction, design and model selection of test equipment, electrical equipment test and scientific research, and has cultivated high-level expert teams, which have won many domestic awards in the field of electrical lab construction. Various testing methods developed by Wuhan NARI have been recommended for use by CIGRE (Council on Large Electric Systems) and IEC (International Electrotechnical Commission).

Engineering–procurement Construction (epc) contractor

Technology Consultation

Supervision

Based on the technological strength and experience of the former Wuhan High Voltage Research Institute (WHVRI), Wuhan NARI can provide supervision and consulting services to the whole manufacturing process of high voltage electrical equipment.

Business Scope:

- Transformer, Reactor, Converter Transformer, Wave Reactor;
- Hybrid GIS (HGIS), GIS, Circuit breaker, isolation switches;
- Capacitor devices, voltage transformer, CVT, lightning arrester, protection casing.

Field Handover Test of Primary Equipment in Substation

Wuhan NARI has the first grade qualification for testing of electric power facilities and is capable to conduct field handover and diagnosis test of primary substation equipment at different voltage levels. With strong expert teams and complete sets of test equipment, the company has successfully accomplished various field tests of major power transmission projects.

Business Scope:

- Transition and diagnostic tests for GIS and GIL (gas-insulated transmission lines);
- Transition and diagnostic tests for transformer and reactor;
- Protective tests and transition tests for cables and lightning arrester etc.

Technology Consultation

Transmission Diagnostics

Wuhan NARI has long been engaged in in-factory supervision and hand over test of power transmission equipment for UHV AC / DC and other major projects. The company has a team of professional talents who are experienced in fault diagnosis, manufacturing, processing and testing for transformer, GIS and other equipment, and are capable of repair and maintenance of all kinds of equipment at different voltage levels.

Business Scope:

- A, B, C, D class maintenance on transformer, reactor and switch;
- A, B, C, D class maintenance on primary equipment such as lightning arrester, capacitor and grounding system;
- Antisepsis of transformers, PRTV (permanent room temperature vulcanized) anti-pollution;
- Auxiliary solutions for filled oil (gas) equipment in oil and gas chemical test;
- Live wire detection auxiliary solutions: infrared temperature measurement, GIS equipment PD, UV, radio waves, oil chromatogram, SF6 gas test.



Training

Wuhan NARI has an experienced team of trainers with a comprehensive and appropriate professional structure, and regularly invites industry experts to give lectures. Training courses are provided all year round.

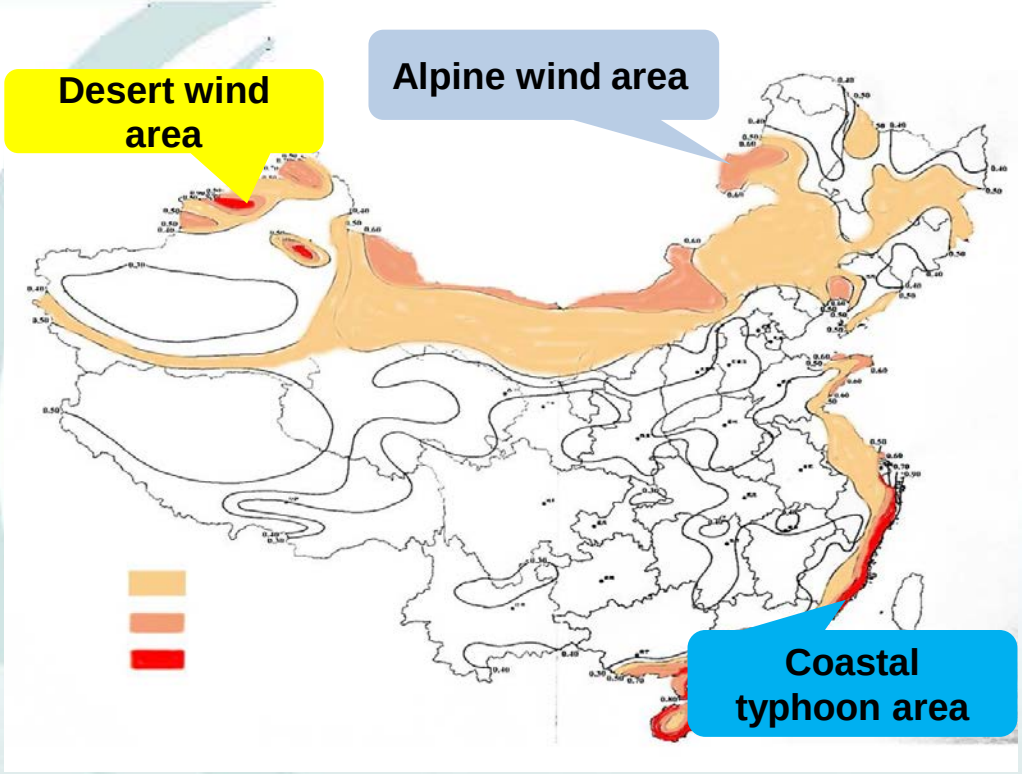
- Training courses on UHV power transmission technologies, grid secure operation (or smart grid), power transmission equipment condition monitoring and maintenance, primary equipment for power transmission and its intellectualization technologies, power cable, power environmental protection technology;
- Training courses on high voltage test methods and standards, insulation preventive test, online monitoring and verification/calibration technologies for test equipment, digital substation, electronic transformer on-site verification technologies, lightning protection and grounding, application of new materials and new energy, etc.


NARI

INTERNATIONAL MARKETING

1. Australia
2. Ecuador
3. Malaysia
4. Vietnam
5. Nigeria
6. Sri Lanka
7. Taiwan

1 INTRODUCTION



Wind hazard distribution in China

Wind hazard distribution in China:

(1) Sandstorm (Northwest);

(2) Alpine wind (Northeast);

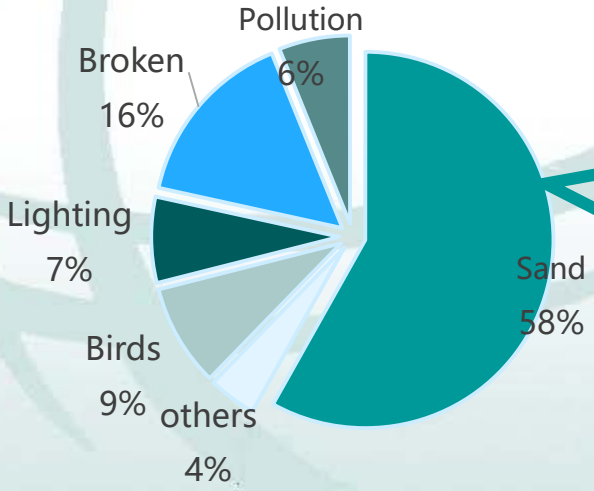
(3) Typhoon (Coast);

(4) Gorge wind (Coteau).

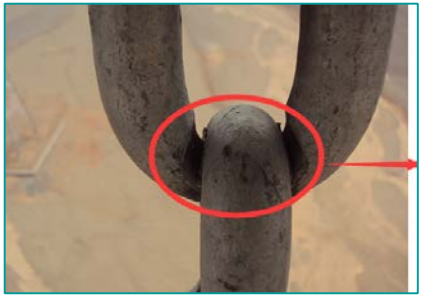
The most serious area is Xinjiang, where sandstorm is frequent and annual average of fresh gale is above 200d/y.

1 INTRODUCTION

In last five years, 58% of the failures are caused by sandstorm in Xinjiang, the main failures are the fault of insulator and hardware.

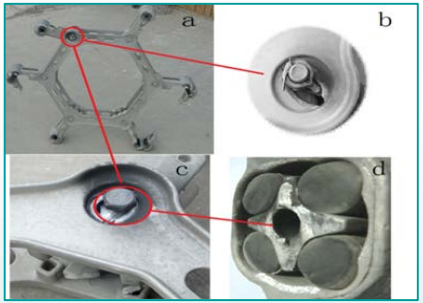


Failure distribution in last five years



Wear failure of U-rings

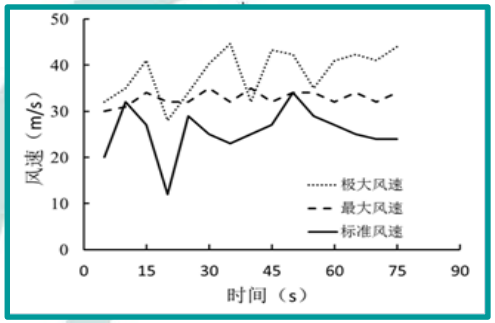
Shed crack of insulators



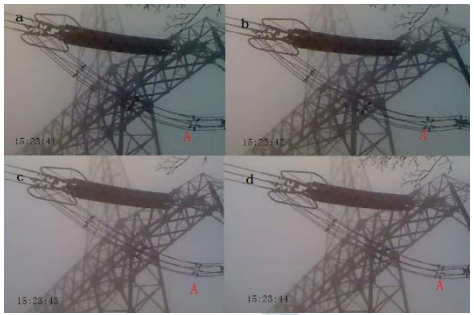
Wind damage on spacers

Sand abrasion of insulator skirt

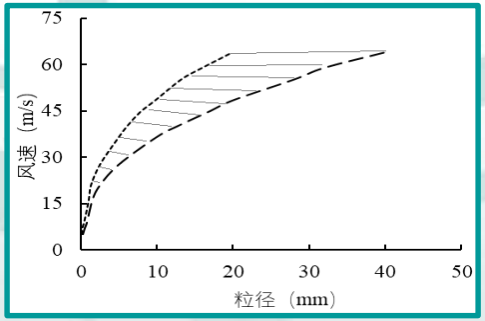
1 INTRODUCTION



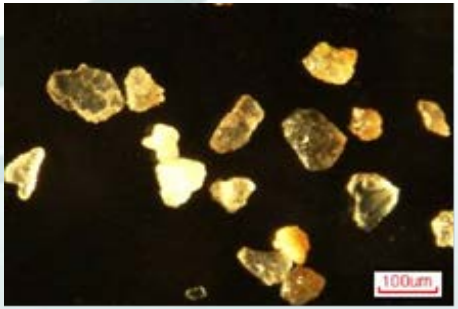
Wind characteristics



Motion trail of the conductor



Sand blowing



Sand

Sandstorm characteristics

(1) Extreme wind speed > 30 m/s;

(2) Wind speed variation > 16m/s;

(3) Sand-blown wind speed: 3~5m/s;

(4) Sand sizes , d< 1.0 mm;

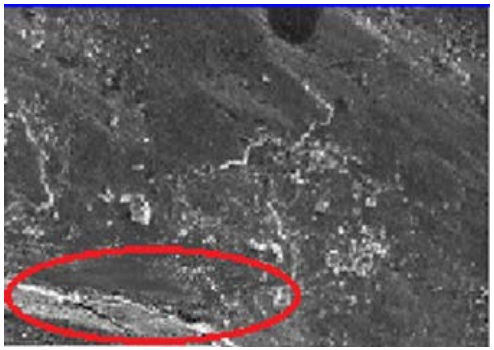
(5) Motion trail period of conductor is about 5 s

1 INTRODUCTION

Hardware failure:

(1) Wear failure of U-rings;
(2) Corrosion;
(3) Wind damage of spacers.

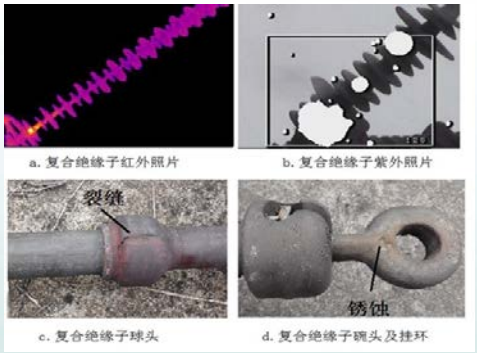
Adhesive wear



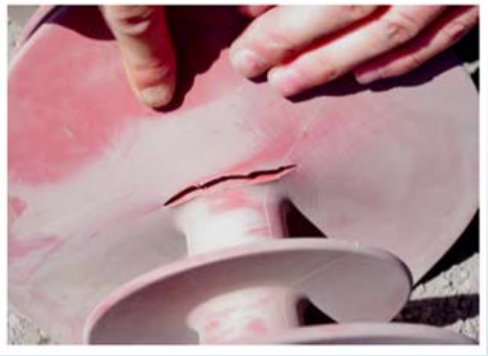
Abrasive wear microanalysis

Insulator failure:

(1) Shed crack of insulators;
(2) Sand abrasion of insulator skirt;
(3) Brittle fracture of rods;
(4) Faulty insulator.



Corrosion



Crack

2 Simulation test and field observation

2.1 Simulation test

Fatigue test

Brittle fracture test on insulator rods

1、Shed crack test on insulator skirt ;
2、Wind damage test on spacers

Simulation test

Wind tunnel

Wear test

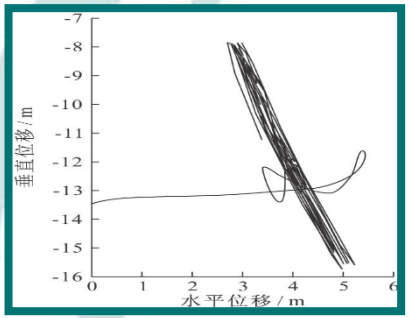
Wear test on U-rings、end-fittings

Sand abrasion test on insulator skirt、hardware

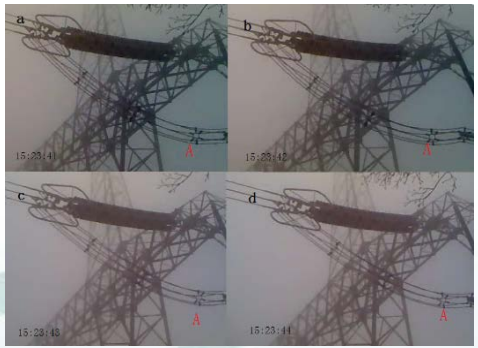
Dusty conditions

2 SIMULATION TEST AND FIELD OBSERVATION

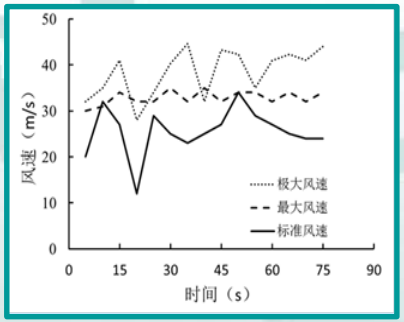
2.2 Field observation



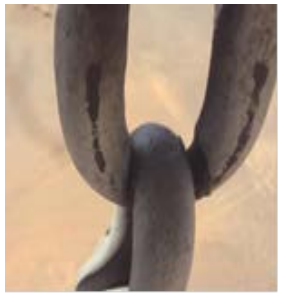
Conductor trace

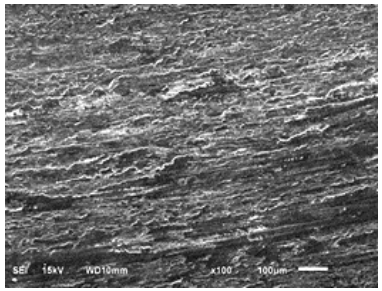


Site photograph

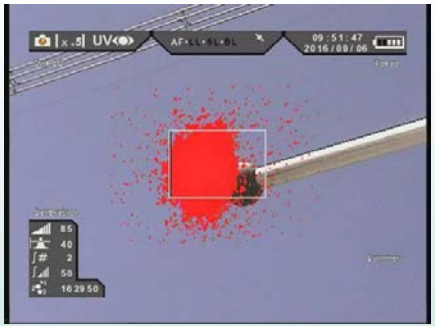


Wind speed data





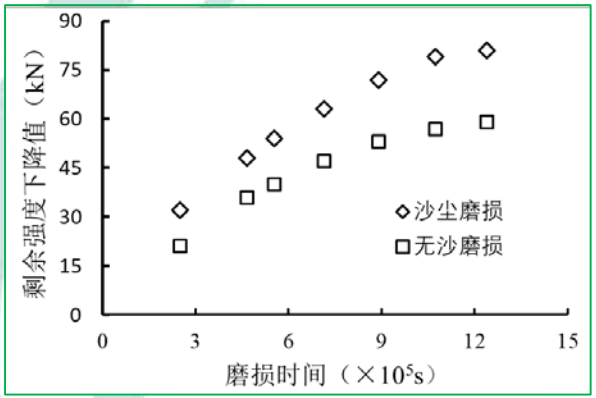
Sampling analysis

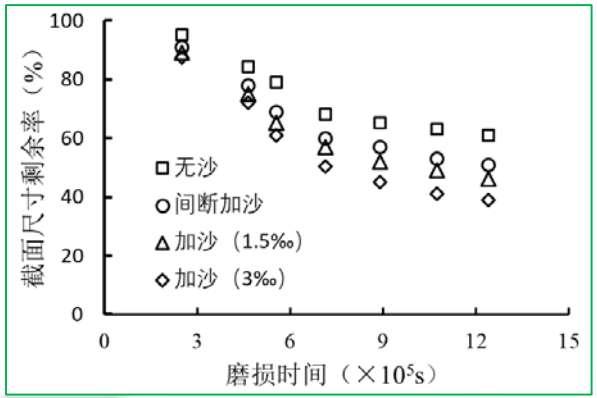


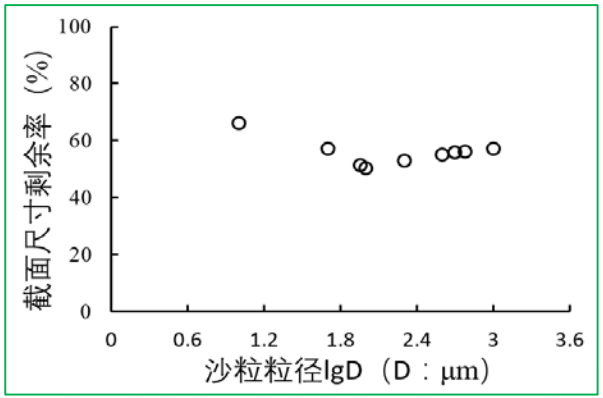
Field measurement

3 FAULT ANALYSIS

3.1 Sand wear







(1)The load and sand flow promote the process of sand erosion, and the sand erosion has the more damage than the erosion without sand.;

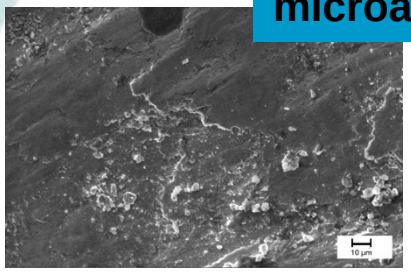
(2)The surplus ratio least value of erosion cross section appears with the sand diameters of about 0.09 mm~0.1 mm.

3 FAULT ANALYSIS

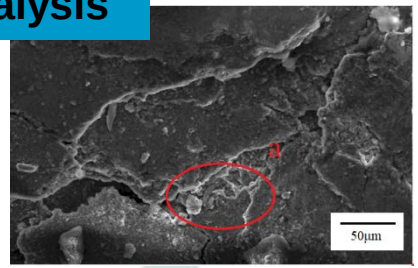
3.1 Sand wear

Abrasive wear microanalysis

Testing sample

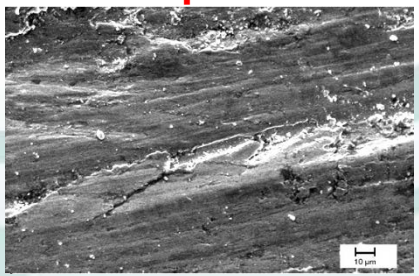


10μm

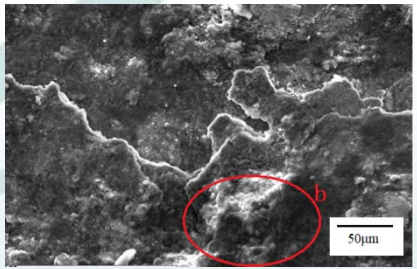


50μm

Field sample

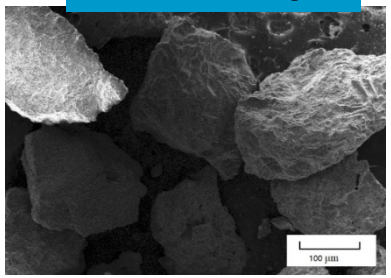


10μm

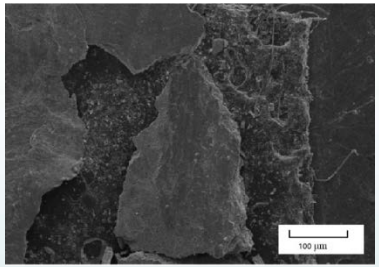


50μm

Sand scraps



100μm



100μm

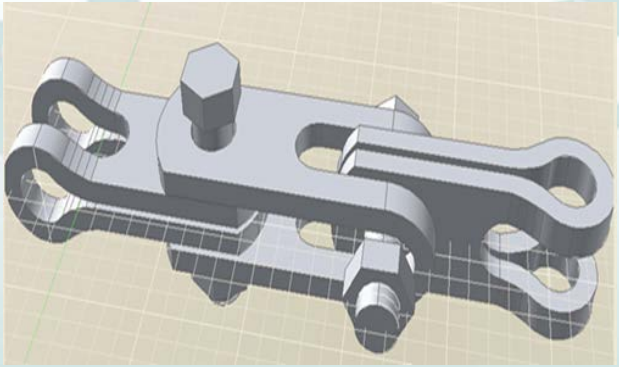
The micro characteristics of adhesion wear and abrasion wear are observed by site and test appearances, and the characteristics of the site and test are similar.

3 FAULT ANALYSIS

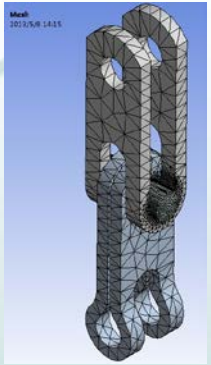
3.1 Sand wear

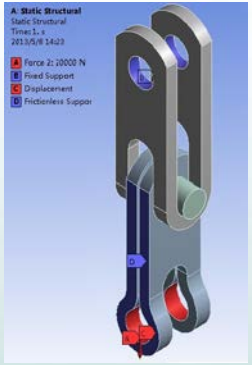
(1) The contact stress of the new structure in the 750kV lines is about 235 MPa, which is only ¼ of that of the U-ring;

(2) The new structure is treated by hot dip galvanizing, which has improved the abrasive resistance.



Structure





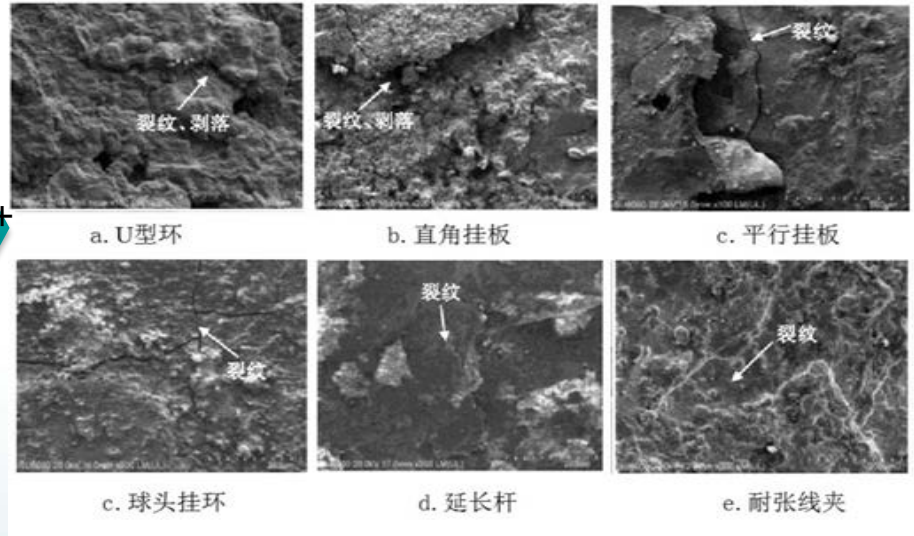
Simulated analysis

Site application

3 FAULT ANALYSIS

3.2 Corrosion

Na^+



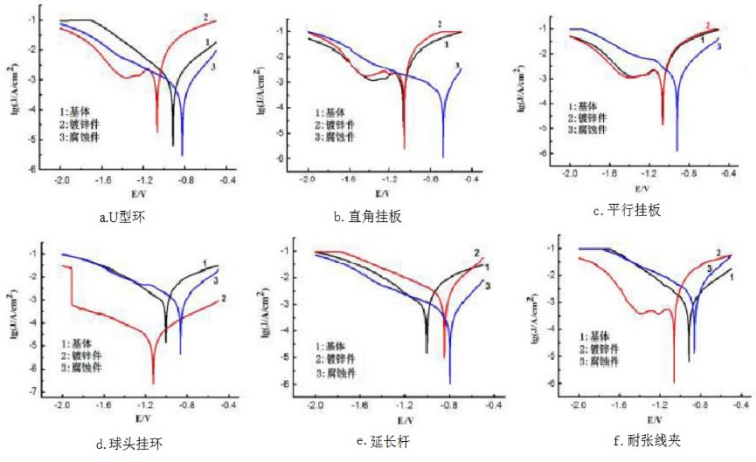
Macro image

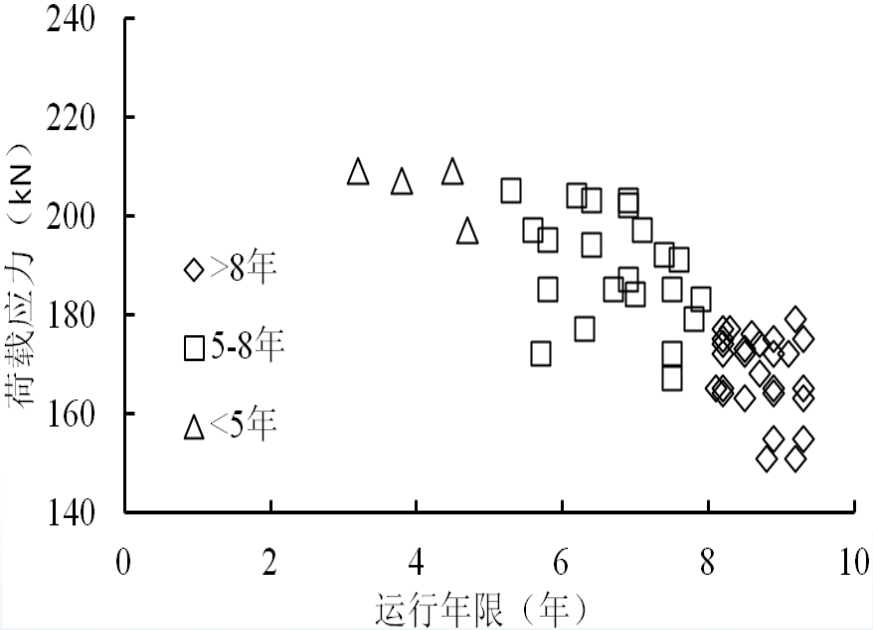
Micro analysis

Soluble salt ions (Ca^{2+}, Na^+, K^+) in sandstorm:
67.17 μg/m³ in PM2.5
202.72 μg/m³ in TSP

3 FAULT ANALYSIS

3.2 Corrosion





(1) The zincs encasement of defect hardware is broken with loose iron oxide forming on the surface of the hardware, and stress load is under 200 kN;

(2) the stress rupture area of composite insulators is at the end fittings, and stress loads of the insulators with working time above 8 years is under 180 kN.

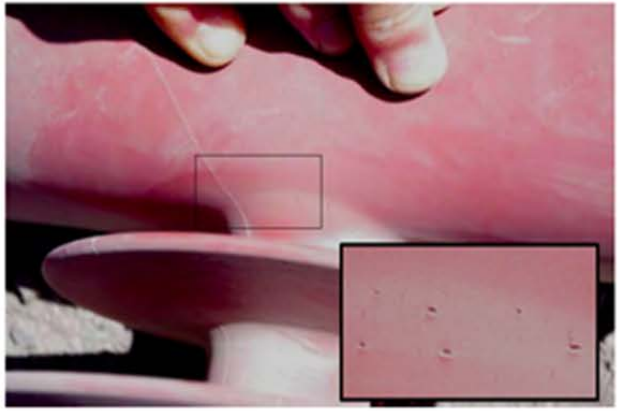
3 Fault analysis

3.3 Shed crack of insulators

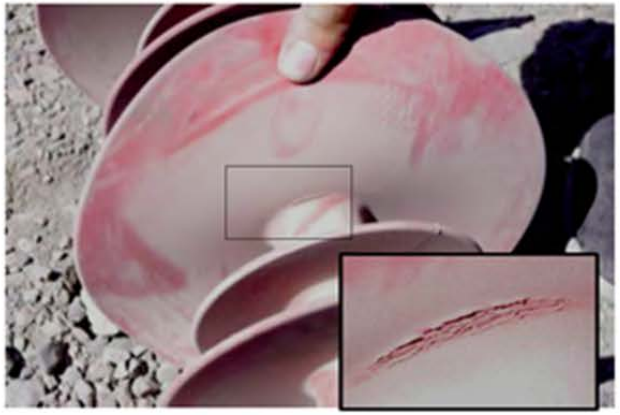
First stage — Needle crack point

Second stage — Hairline crack

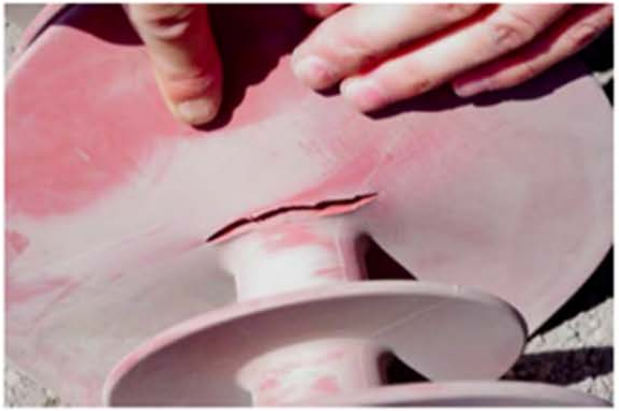
Third stage — Endurance crack



(a) 初期的针刺点



(b) 发展为细微裂纹

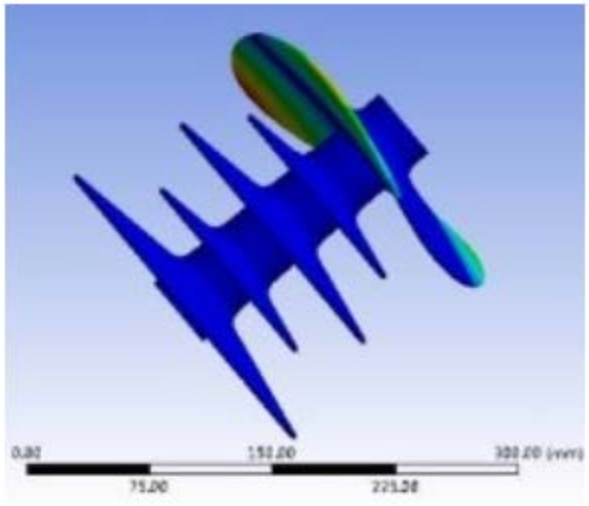
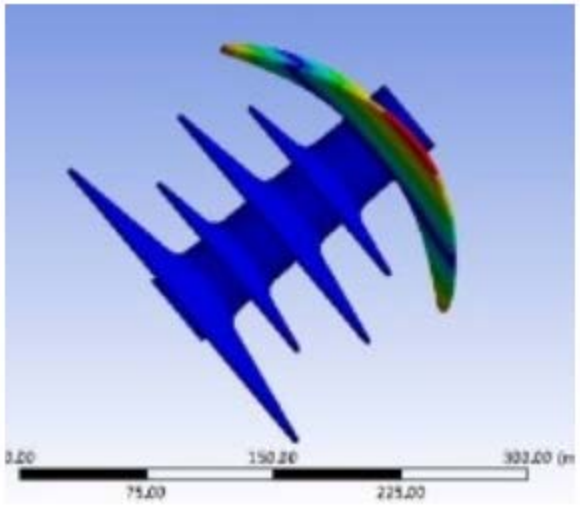
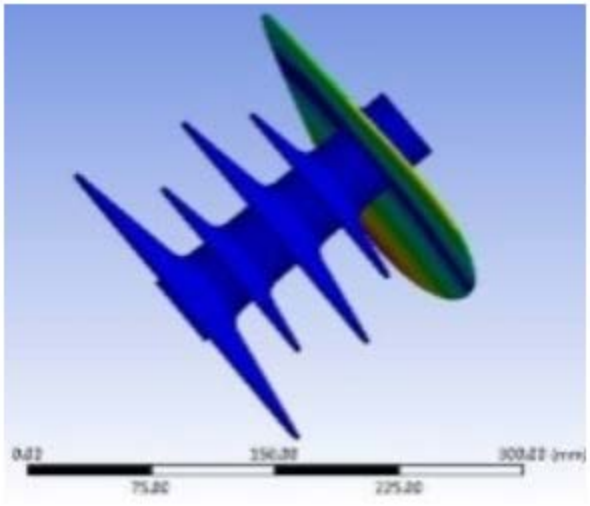


(c) 伞裙根部疲劳裂纹

Reference: ZHU Z, JIA Z, MA G, et al. IEEE Transactions on Dielectrics and Electrical Insulation, 2015, 22(3): 1636-1643.

3 FAULT ANALYSIS

3.3 Shed crack of insulators

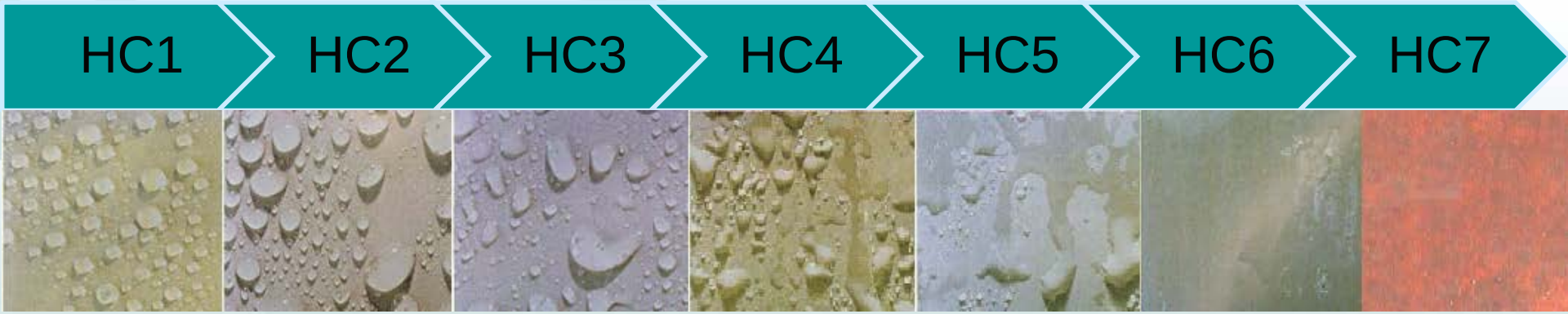
(1) With the suspension type V string, various inclination angles were tested and the critical angle that leads to lowest inception wind velocity is 50° ;

(2) The extinction wind velocity is normally lower than inception wind velocity and the gap can reach 17.6%

3 FAULT ANALYSIS

3.4 Sand abrasion of insulator skirt

After 1 year operation in sandstorm areas, the hydrophobicity of skirt has declined from HC1 to HC3.



3 FAULT ANALYSIS

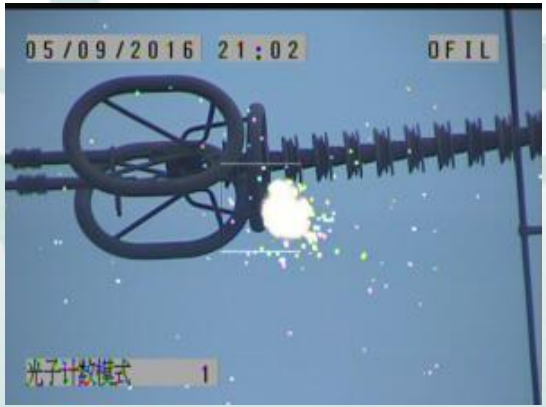
3.5 Corona

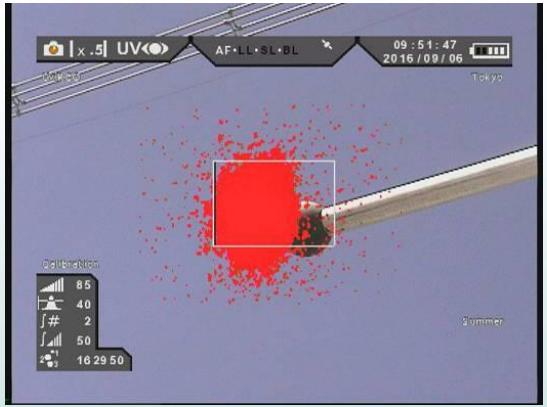
Corona discharges are easily captured around the hardware，where are damaged by the sand storm. The effect factors include:

(1) wind damage;

(2) sand storm surroundings;

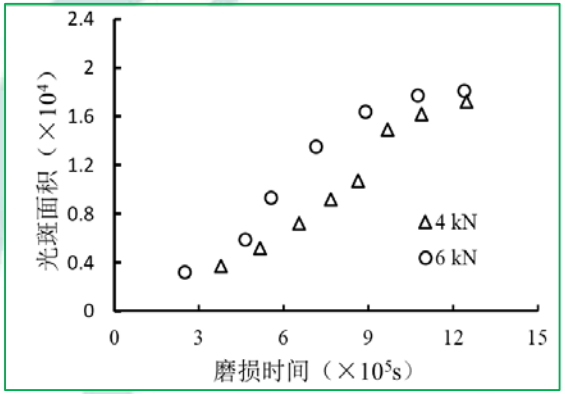
(3) sand abrasion and corrosion.

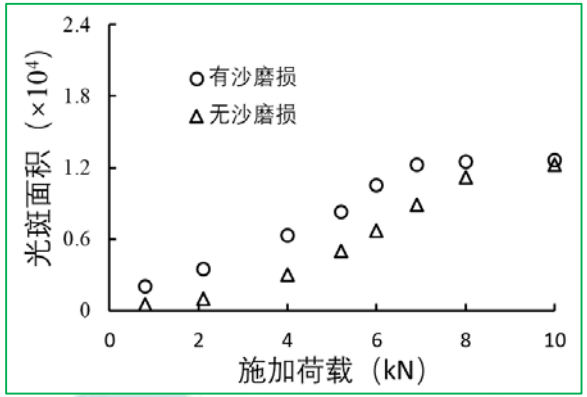


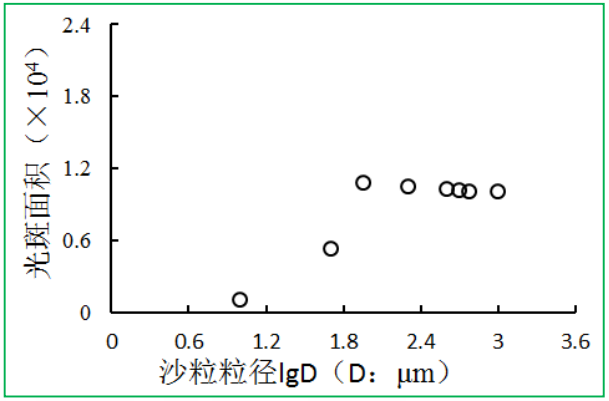


3 FAULT ANALYSIS

3.5 Corona





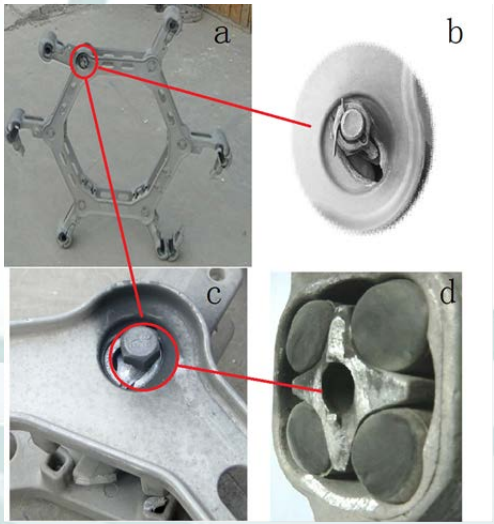


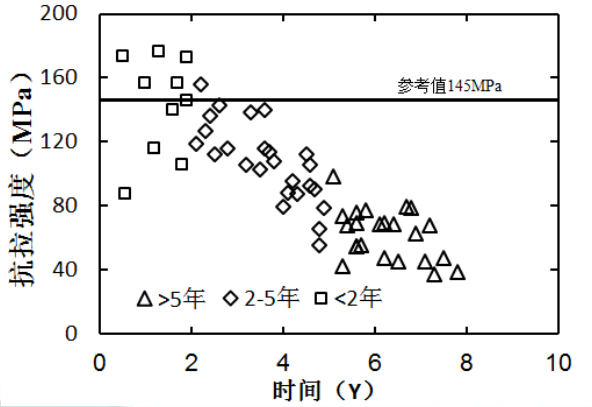
(1) The sizes of corona spots have the saturation positive correlation with the sand erosion time and stress, respectively;

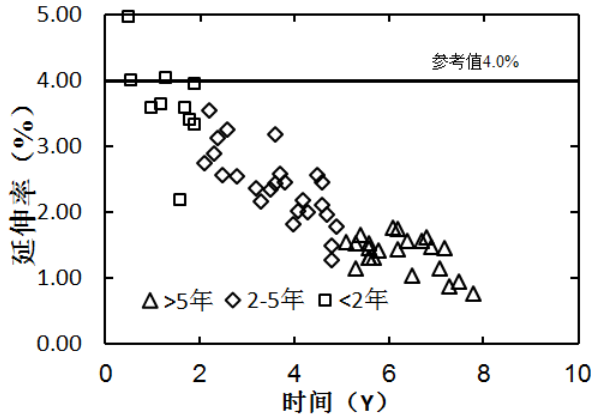
(2) The sizes of corona spots rise with the sand diameters quickly to peak value, and decline gradually, and peak value appears with the sand diameters of about 0.09 mm~0.1 mm.

3 FAULT ANALYSIS

3.6 Wind damage on spacers

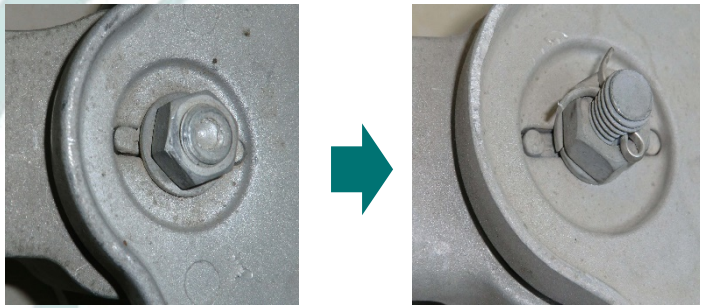






The mechanical testing and structural analysis reveals the negative correlation between the failure and the running time of wind damage.

3.6 Wind damage on spacers

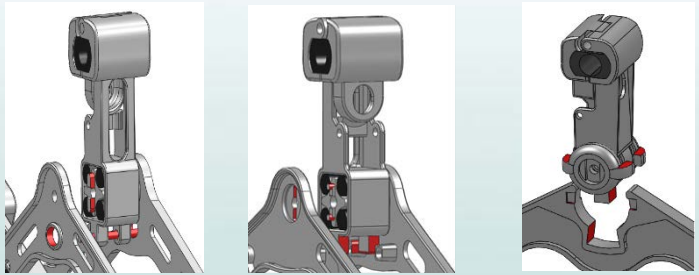


Connection type of bundle-conductors: adopting spring and pin way to prevent the loosening of spacers.

The selection suggestion of bundle-conductor spacers:

(1) The contact areas of the restriction sites are relatively large;

(2) The contact areas are under static friction state.



4 CONCLUSION

In sandstorm area, the fault of insulator and hardware is the main failures of transmission lines.

Hardware failures include wear failure of U-rings, corrosion, wind damage of spacers, and insulator failures include shed crack of insulators, sand abrasion of insulator skirt, brittle fracture of rods and faulty insulator.

The main effect factors on failures are:

(1) Extreme speed wind;

(2) Sand-blown wind;

(3) **Soluble salt ions (Ca^{2+}, Na^{+}, K^{+}) in sandstorm**

THANKS