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Common quality problems and prevention measures in the installation of high and low voltage distribution equipment

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Abstract: High and low voltage distribution equipment is the core hub of the user side power system, and its installation quality directly affects the reliability of power supply, equipment life, and electrical safety. In the current construction of industrial and civil power distribution engineering, common quality problems such as poor terminal crimping, illegal cable laying, and grounding failure are frequently caused by non-standard processes, lack of control, and insufficient personnel skills. These problems can easily lead to equipment heating, insulation breakdown, short circuit power outages, and electrical fires, resulting in significant power losses. This article combines the practice of power distribution room renovation projects, strictly follows the national electrical acceptance specifications and the operating standards of Southern Power Grid, sorts out the manifestations, hazards, and causes of typical quality problems in power distribution installation, and formulates preventive measures from the aspects of process control, inspection standards, environmental protection, and management mechanisms, clarifying key process technical parameters and acceptance indicators. The research results can provide practical reference for quality control of similar distribution installation projects, effectively reduce equipment failures, and improve the level of power supply safety.

1. Introduction

The low-voltage distribution network is an organic component of the entire power grid, and once a fault occurs, it will bring huge harm and economic losses to the power grid. The practical implementation of installation and commissioning projects for distribution equipment and devices is closely related to the safety, stability, and reliable operation of the power grid. Some construction units have lax control, inadequate implementation of processes, and lack of inspection work, resulting in problems such as joint heating, insulation degradation, and grounding failure after equipment is put into operation, increasing operation and maintenance costs, and posing potential risks of power outages and safety accidents. The existing construction plan has shortcomings in the management of common quality problems and regional adaptation control. Based on relevant specifications and standards, this article analyzes the causes and risks of common quality problems in high-frequency installation, proposes a complete set of standardized prevention and control

measures, and provides technical support for improving the quality of industrial distribution installation.

2. Common quality issues in the installation of high and low voltage distribution equipment

2.1 Poor crimping of wiring terminals

Poor terminal crimping is the main heat hazard in low-voltage distribution. Improper crimping can cause the effective contact area to be less than 30% of the design value, resulting in a significant increase in contact resistance. In this project, the 240mm ^{2}copper terminal generates 8.7 $\times 10^8$ J of heat per hour under a contact resistance of 0.8 Ω, with a temperature rise exceeding 200 ℃ in 1 hour, causing insulation breakdown and resulting in phase to phase short circuit. Construction issues such as mold mismatch, mold wear, and single point crimping have led to substandard crimping quality. The high humidity salt spray environment in Gaoming causes the terminal contact resistance to increase by 15% -20% annually. After 2-3 years of operation, overheating faults occur frequently, and the resistivity of inferior copper terminals exceeds the standard by 20%. Visual inspection cannot detect internal virtual connection defects, and problems such as chaotic terminal layout, insufficient wire margin, and label detachment can lead to control circuit abnormalities and difficult maintenance in the later stage. The failure of high current critical circuit terminals can directly cause power outages throughout the plant[1].

2.2 Improper cable laying

Improper cable laying can easily leave insulation damage hazards. When the bending radius of the cable is less than 20 times the outer diameter standard and reduced to 8-12D, the insulation tensile strain exceeds 15%, and the insulation life is shortened by more than 60%. The average annual humidity in Gaoming area is over 75%, and unclosed holes can allow water vapor and dust to enter the cabinet. After condensation, the flashover voltage along the surface drops to a dry state of 20% -30%, and the risk of short circuit increases significantly. The installation deviation of high-voltage cable terminals exceeds 5mm, and the electric field concentration coefficient is increased by 2-3 times. Long term operation can cause partial discharge and insulation breakdown. The cable trench is not sloped, and the support is corrosion-resistant and damaged, resulting in water accumulation and corrosion. The cable armor is perforated and ineffective for 3-5 years. Relying solely on color for phase identification on site can easily lead to phase sequence errors, causing grid connection failures. The lack of fireproof sealing can cause the fire to spread rapidly along the cable trench, expanding accident losses (Table 1).

Table 1 Common Quality Problems and Hazardous Parameters in Cable Laying

Common Defect Type	Specification Requirement	Measured Value of Typical Defect	Main Hazards
Insufficient Cable Bending Radius	Multi-core ≥15D, Single-core ≥20D (D is cable diameter)	—	Mechanical damage of insulation layer, partial discharge; exceeding standard, service life reduced by over 40%
Unsealed Hole	Sealed with fire blocking material / sealing fittings	Gap width: 5~20 mm	Invasion of dust and moisture; insulation resistance reduced by over 60% in humid environment
Excessive Grounding Resistance	Grounding resistance of cable support ≤4 Ω	8~15 Ω	Cable support may be energized during fault; higher risk of

			electric shock
Missing Markings	Markings to be installed every 10~15 m, at bends and joints	Markings only at start and end	Fault location time prolonged by 2~3 times; longer power outage duration

Note: D is the outer diameter of the cable, and the data refers to GB50168-2018 "Construction and Acceptance Standards for Cable Lines in Electrical Equipment Installation Engineering" and engineering measurement statistics

2.3 Insufficient burial depth of grounding electrode and unreliable grounding connection

Improper grounding construction can cause the grounding system to fail, posing risks of electric shock and equipment damage. When the surface soil resistivity fluctuates by 3-5 times and the grounding electrode is buried less than 0.6m deep, the grounding resistance exceeds 20 Ω during the dry season, making it impossible to discharge fault current. When the fault current is 100A and the grounding resistance is 10 Ω, the contact voltage reaches 1000V, far exceeding the safe voltage of 36V. The effective conductive cross-section of single-sided welding of flat steel is only 40% of the standard, and the mechanical strength decreases by 50%. The weld seam is prone to melting under short-circuit current. The high water content soil in the local area causes the corrosion rate of grounding components to be 2-3 times that of dry areas. If the anti-corrosion is not in place, it can rust and break within 3-5 years. Failure to remove the oxide layer from the grounding connection, lack of anti loosening accessories, and incorrect cable grounding methods can all lead to excessive grounding resistance, circuit failure, and inadequate sealing and anti small animal measures, which can easily cause grounding short circuit faults[2].

2.4 Non standardized busbar connection

Defects in the construction of busbar joints are an important cause of electrical fires. When the busbar overlap surface is not polished, the effective contact area is less than 10%, and the contact resistance is 5-10 times the qualified value. According to industry statistics, 80% of power distribution burnout accidents are caused by busbar overheating. For every 10 ℃ increase in joint temperature, the insulation aging rate doubles. Expanding the bolt hole by 2mm will reduce the current carrying section of a single hole by 8%, and the overall current carrying capacity will decrease by more than 15%. In the high humidity environment of the south, the busbar stored outdoors is prone to oxidation and moisture, and the insulation resistance can be reduced to below 1M Ω, which can easily cause phase flashover during power transmission. The pre tightening force attenuation of 4.8 grade bolts is much higher than that of 8.8 grade high-strength bolts. Construction without calibrated torque wrenches results in a pre tightening force dispersion coefficient exceeding 40%, which can easily cause looseness, tooth slippage, phase sequence disorder of busbars, insulator cracks, and loose fixation, leading to poor contact, overheating of joints under grid connected impact currents, and grid connection failure[3].

3. Prevention and control measures for common quality problems in the installation of high and low voltage distribution equipment

3.1 Quality control of crimping of wiring terminals

The terminal crimping construction shall follow the first piece approval system, and samples shall be made according to different wire cross-sections. After passing the acceptance, they shall be used as batch construction standards. The incoming terminals must have a certificate of

qualification and a testing report. National standard copper tin plated terminals are preferred. DC resistance is sampled and tested upon entry. Any products that exceed the standard are returned. The crimping tools and molds are regularly calibrated, and worn-out molds are replaced in a timely manner. Special wire stripping pliers are used for wire construction. The stripping length should have an error of ≤ 2mm compared to the depth of the terminal cavity. If the wire core breakage rate is greater than 1%, the wire must be stripped again. For large section terminals of 240mm ^{2} and above, the surrounding pressure process should be used, with no less than three crimping passes. The indentation should overlap by 1/3 of the width. After crimping, the terminal should have no cracks or deformations, and the indentation depth should meet the calibration standards. Burrs should be cleaned in a timely manner and the wire core should be protected.

Implement three-level inspection during construction, with 100% self inspection by the team, and immediately rework any non-conforming items; 30% sampling inspection is conducted in the work area, and the resistance of high current circuit joints is not greater than 1.2 times that of equal length wires, with an absolute value of less than 1m Ω. The project department conducts 100% final inspection on key circuits such as generator cabinets and parallel cabinets, completes torque tightening, and applies anti loosening paint. Separate the strong and weak electrical circuits inside the cabinet, tie the wiring harness neatly, and make a curved transition when turning. Install machine printed flame-retardant wire number tubes at both ends of the wire, with markings consistent with the drawings. Copper aluminum joints must use dedicated transition terminals to prevent corrosion problems caused by direct crimping[4].

3.2 Control of the entire process of cable laying

Complete on-site survey before cable laying, draw the laying path diagram, calculate the turning radius, and meet the specifications of 15D multi-core cable and 20D single core cable. Check the parameters and integrity of the outer sheath when the cable enters the site. The insulation resistance of 10kV cables should be ≥ 1000M Ω, and that of 0.4kV cables should be ≥ 10M Ω. Unqualified products are prohibited from entering the site. The laying traction speed should be ≤ 15m/min, and the traction force of copper core cables should be ≤ 70N/mm ^{2}. Special mesh covers should be used for traction, and the cable sheath should not be pulled directly. Cable supports shall be arranged according to standards, with a horizontal power cable spacing of ≤ 1.5m, a control cable spacing of ≤ 1m, and a vertical laying spacing of ≤ 2m. The entire support shall be reliably grounded, and rust proof paint shall be applied to damaged galvanized areas.

Before cable threading, burrs on the pipe mouth should be treated, protective covers should be installed, debris and accumulated water inside the pipe should be cleaned, and neutral talcum powder should be applied to reduce wear during threading. The production environment for high-voltage cable terminations should have a temperature of ≥ 5 ℃ and a relative humidity of ＜ 70%. Outdoor operations are prohibited in severe weather conditions. Certified personnel should follow standard procedures to ensure the quality of insulation and semiconductor layer construction. Each process should be cleaned with specialized paper towels in one direction. After the installation is completed, special tests will be carried out to check the insulation resistance and phase sequence of low-voltage cables, and to add DC resistance and AC withstand voltage tests to high-voltage cables. The deviation between the test data and the factory value should be ≤ 10%. Fire retardant signs shall be hung uniformly at cable sections, bends, and end positions. The construction unit shall implement fire and moisture prevention measures simultaneously, seal the holes with fireproof blocking materials, set fireproof partition walls every 50m and collection wells every 20m in the cable trench, set a drainage slope of 0.5% in the trench, and install rain covers at outdoor terminals[5].

3.3 Standardized construction of grounding system

Before grounding construction, the soil resistivity is tested. The conventional value in Gaoming area is 50-200 Ω· m. If the value exceeds the standard, methods such as adding grounding electrodes, expanding the grounding grid, and applying resistance reducing agents can be used to meet the standard. The vertical grounding electrode adopts ∠ 50 ×5 hot-dip galvanized angle steel, with a single length of 2.5m and a buried top distance of ≥ 0.8m from the ground; the horizontal grounding body adopts -40 ×4 hot-dip galvanized flat steel, which is reliably welded to the vertical grounding electrode. Flat steel lap length ≥ 2 times width, fully welded on three sides, round steel lap length ≥ 6 times diameter, double-sided welding, weld seam height ≥ 6mm, no welding defects, thoroughly cleaned of slag after welding, coated with anti rust paint and asphalt anti-corrosion paint successively, with anti-corrosion coverage of 100mm on both sides of the weld seam. The exposed height of the grounding main line is 250-300mm, the horizontal support spacing is 1m, the turning spacing is 0.5m, and the bending radius of the turning arc is ≥ 10 times the width of the flat steel.

Concealed grounding works must be inspected and accepted by the supervisor, and image data must be retained. Only after passing the inspection can backfilling be carried out. A single distribution cabinet is equipped with independent grounding terminals and grounding branch lines, and series grounding is prohibited. The grounding bolts are made of M8 or above galvanized bolts, and the contact surfaces are polished, rust removed, and coated with electrical compound grease before being tightened. The metal movable panel of the cabinet adopts ≥ 4mm ² copper core flexible wire jumper to achieve overall equipotential. Double layer sealing shall be applied to the holes in the distribution room, waterproof and rodent proof facilities shall be installed, and the grounding resistance shall be monitored in dry weather. The grounding resistance of the low-voltage system shall be ≤ 4 Ω and shall not be tested for 3 days after rain. If the resistance exceeds the standard, grounding electrodes shall be added or a long-term resistance reducing agent with a thickness of ≥ 50mm shall be wrapped. The project can only be completed after passing the retest.

3.4 Fine management of busbar connection

The qualification documents and appearance quality of the busbar shall be verified upon entry. The insulation resistance of the low-voltage busbar shall be ≥ 20M Ω, and the high-voltage busbar shall be ≥ 1000M Ω. The damp busbar shall be dried and retested before use. The overlapping surface of the busbar should be longitudinally polished and cleaned with 0-grit sandpaper, wiped dry with anhydrous ethanol, and evenly coated with 0.2mm thick electric composite grease, avoiding bolt holes. Transition plates must be installed for copper aluminum busbar connections to prevent electrochemical corrosion. The busbars are strictly arranged in accordance with the standard phase sequence, with corresponding color markings.

The busbar is connected with 8.8 grade high-strength bolts and tightened in two steps using a calibrated torque wrench. First, it is symmetrically tightened with 50% standard torque, and then fully tightened after alignment and fitting to avoid busbar deformation. Uniform color codes shall be made for fastening bolts, and quality inspectors shall conduct 100% torque sampling and record data. After the installation of the busbar is completed, the insulation resistance shall be retested to verify the installation flatness and phase sequence accuracy. The high current circuit is powered on and operated for 4 hours. The temperature rise of the infrared detection joint is ≤ 30K, and the temperature difference between the joint and the busbar is ≤ 5K. The busbar is stored with a 300mm height pad and placed in a dry and ventilated area. It is strictly prohibited to store it outdoors. Rainproof and moisture-proof measures should be taken during the rainy season, and secondary cleaning and testing should be carried out before installation. A protective cover plate should be added to the busbar room, and a ventilation channel should be reserved to prevent foreign objects

from short circuiting and ensure equipment heat dissipation (Table 2).

Table 2 Tightening Torque Standards for Low Voltage Busbar Connection Bolts

Bolt Size	Material	Standard Tightening Torque (N·m)	Applicable Busbar Current Rating
M8	Class 8.8 High-strength Steel	18~22	630A and below
M10	Class 8.8 High-strength Steel	32~38	1000~1600A
M12	Class 8.8 High-strength Steel	50~60	2000~2500A
M16	Class 8.8 High-strength Steel	110~130	3150~4000A

Note: Referring to GB50149-2010 "Code for Construction and Acceptance of Busbar Devices in Electrical Equipment Installation Engineering", the contact surface should have no gap after tightening

3.5 Installation positioning and environmental protection

The equipment foundation channel steel should be accurately leveled before installation, with a horizontal deviation of ≤ 1mm/m and a total length deviation of ≤ 5mm after installation. The channel steel should be reliably connected to the grounding main line at least at two points. Cabinets are installed in place one by one, with a verticality deviation of ≤ 1.5mm/m, a flatness deviation of ≤ 5mm for rows of cabinets, and a joint width of ≤ 2mm. Cabinets are fixed to the foundation channel steel bolts, and shock-absorbing pads are installed to ensure stable operation. The diesel generator can only be installed after the strength of the foundation concrete meets the standard. The horizontal deviation of the equipment should be ≤ 0.1mm/m, the radial deviation of the coupling should be ≤ 0.05mm, and the end face deviation should be ≤ 0.02mm. All equipment installation data should be fully archived and included in the project acceptance data.

The distribution room adopts a combined ventilation method, with a ventilation rate of not less than 6 times per hour. In summer, the indoor temperature is controlled within 40 ℃. According to the characteristics of the local high humidity climate, dehumidification equipment is configured to stabilize the indoor humidity at 40% -70%. The cabinet is equipped with condensation dehumidification devices. The project department installed a G4 level dust filter at the air inlet, sealed the doors and windows well, and reduced dust accumulation; Set up 1.2m protective railings and warning signs in the high-voltage area, lay insulation rubber pads with a thickness of ⩾ 5mm in front of the cabinet, and ensure that the passage in front of the high and low voltage cabinets is not less than 1.5m and 1.2m respectively. The project department shall equip the site with sufficient fire-fighting equipment and conduct regular inspections, implement protective measures such as rodent prevention and sealing, conduct regular inspections, and eliminate safety hazards in equipment operation.

4. Conclusion

The installation of high and low voltage distribution equipment covers multiple construction stages, and even minor defects can cause equipment failures and safety hazards. Construction quality issues are affected by personnel skills, process implementation, on-site environment, and control systems. The high humidity and high groundwater level conditions in the Pearl River Delta region can amplify the adverse effects of installation defects. This article combines the practice of local enterprise power distribution renovation projects to analyze the fault mechanisms and underlying causes of installation quality defects, develop quantifiable standardized prevention and control plans, and clarify the process parameters and acceptance control standards of key processes.

Practice has shown that implementing first article approval, three-level inspection, and refined control can effectively reduce quality problems, improve project acceptance quality, and reduce later operation and maintenance failures. All participating units need to strictly implement standard specifications, strengthen process supervision, optimize construction plans that are suitable for the on-site environment, improve the full cycle quality control system, and play an important role in stabilizing industrial power supply, reducing operation and maintenance expenses, and building a strong power safety defense line.

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