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Broken Insulation Repair Based on Two-component Sub-polymer Resin Technology

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Abstract

During the installation and use of cables, micro-damage or micro-cracks in the insulation and sheath materials of cables inevitably occur due to external factors as well as their own ageing, and it is difficult to detect minor defects within the cables with existing inspection techniques. During cable operation, micro-cracks within the insulation material can trigger and accelerate the growth of electrical branches under the action of a continuous electric field, eventually breaking through the insulation material and causing irreparable disaster. In China's economic growth, power demand is growing, how to ensure the safe and reliable operation of electricity is a major problem in the operation and maintenance of power grids, whether above ground power cables or directly buried underground laying power cables, can not solve the power cable outer insulation layer damage in a timely manner, there is a great safety risk in the process of operation. The need to study a power cable outside the emergency repair materials and special supporting utensils, can quickly match a variety of field applications, timely repair of power cable outer insulation layer damage, to the power enterprise power production and the development of the local economy to bring protection, to avoid the power cable leakage caused by personal safety and productive accidents.

Keywords

Two-Component Substrate, High Polymer Resin, Insulation Breakage Repair

1. Introduction

With the continuous progress of economic technology, people's demand for electricity is getting bigger and bigger, the quality and reliability of power supply requirements are also getting higher and higher, China's electric power industry in the new is to the competitive pressure of the development speed is also getting faster and faster, the power enterprise to the application of high-voltage cable is also getting bigger and bigger, and power cable is often divided into underground power cable and above ground power cable, or indoor and outdoor two parts. At present, the general operating environment for laying power cables is relatively simple, in the laying of power cables operation site due to some of the collision of instruments or unconscious construction personnel knocked bad power cable insulation layer on the outer surface, resulting in a point of power cable or a few points will occur leakage phenomenon, and due to external environmental factors, there will inevitably be the phenomenon of aging erosion, will also occur rupture, resulting in the operation of the process is prone to certain leakage electrocution accidents or grid operation

accidents, most of which can be summarised as a result of the breakage of the outer protective layer leading to further damage to the main insulation layer of the cable.

In China's growing economy, the demand for electricity is growing, how to ensure the safe and reliable operation of electricity is a major problem in the operation and maintenance of power grids, whether it is above ground power cables or directly buried underground power cables, can not solve the power cable outer insulation layer damage in a timely manner, there is a great safety risk in the process of operation. In view of this, there is a need to study a kind of power cable outside the emergency repair materials and special supporting tools, can quickly match a variety of field applications, timely repair of power cable outside the insulation layer of the broken problem, to the power enterprise power production and the development of the local economy to bring protection, to avoid the power cable leakage caused by personal safety and productive accidents. Therefore, in view of the above-mentioned related problems, we carried out the special research on "research and application of emergency repair of cable outer insulation layer damage".

2. The need for insulation damage repair

With the massive development of our urban power grids, power cables are widely used, but after long term operation of power cables, water tree defects can develop in localised areas of the outer insulation. The water tree is usually described as a dendritic insulation defect formed by nano-scale channels and water-filled micro-pores, and is one of the main causes of insulation ageing in low and medium voltage power cables. The new For the water tree problem, the newly developed power cable to water tree effect are greatly improved, but the early into the ground power cable is not water tree resistant power cable, for this problem, domestic and foreign development of a silicone repair fluid, so that it diffuses to the insulation inside the water tree area to consume water, while the generation of polymer organic material to fill the water tree area, according to the data of its operation, this technology can effectively extend the life of power cable up to More than 20 years, China's power cables have not yet entered the aging failure period, this aspect of the study is still relatively small, some domestic research institutions through laboratory research to confirm the feasibility of the technology. At present, the domestic for such repair technology for field operation of aging and damaged power cable modification lack of research, related engineering application technology and field repair effect is rarely reported. To sum up, the project power cable outside was broken emergency repair research is the main development trend of the future power enterprises safe and stable transmission of power production and operation, but also the direction of China's power enterprises focus on.

At present, the majority of low-voltage cable insulation layer using rubber as insulation material, due to the role of external factors, oxidation decomposition of the electro-physical and mechanical properties of vulcanized rubber, making the bare low-voltage cable insulation layer aging rapidly, and eventually insulation breakdown or short circuit phenomenon. The insulation layer of the low-voltage cable is exposed to the air for a long time, in addition to solar irradiation and thermal radiation, it is also subject to weathering and stripping by the elements, and in less than 2 to 3 years of operation, the insulation layer of the exposed low-voltage cable starts to age and crack, and over time the cracking intensifies and even falls off as a block, resulting in part of the low-voltage cable being exposed to the air, moisture, foreign objects falling, insufficient safety distance, etc. This can lead to accidents such as electric shock, insulation breakdown or short-circuiting of low-voltage cables, bringing unstable factors to the operation of substations' substation equipment and relay protection devices, as well as leaving serious hidden dangers to the safe and stable operation of substation equipment.

3. Technical introduction to the repair of broken insulation

3.1 Technology for power cable insulation

Power cables are a common material in power engineering projects, and their insulation is usually made of plastic, PVC and other chemical materials. At the same time, the traditional high-capacity overhead transmission method in terms of architectural neatness and beauty can no longer meet the needs of modern cities, power cables are widely used in urban construction for their large transmission capacity, ease of installation and environmental friendliness. During the operation of a cable, its insulation is subjected to simultaneous or continuous electrical, thermal, mechanical and environmental stresses. These stresses contribute to the initiation and development of certain XLPE degradation processes, resulting in some irreversible deterioration of the physical and chemical properties of the insulation.

As one of the important power equipment in urban transmission and distribution networks, power cables have the advantages of being less affected by external factors (lightning, strong winds, bird damage, etc.), high reliability of power supply, low impact on urban appearance and improvement of line power factor, thus, power power cables are increasingly used in urban transmission and distribution networks. With the country's economic development, the length of power cables laid in various places is also increasing exponentially. Improve the transmission power cable operation and maintenance level, to protect the health of the operating power cable, is to reduce the power cable line accident rate of the important guarantee.

Power cable outer sheath is located in the outermost layer of the power cable, mostly using PVC or PE and other materials, its main role is to protect the power cable in transport, laying and damage, protect the metal sheath from external damage, moisture and corrosion, etc., for no metal sheath of the power cable is directly play a sealing and protection of the main insulation role. Q/CSG114002-2011 power equipment preventive experimental procedures, the power cable sheath should meet: per kilometre insulation resistance should not be less than 0.5MΩ (i.e. 0.5MΩ-km); in the metal shield or metal jacket and ground between the DC voltage 5kV, the pressure time of 1min, no breakdown.

Because there are few cases of power cable line blackout directly caused by the outer sheath insulation resistance reduction, resulting in significant economic loss, and outer sheath defects positioning maintenance requires a lot of human and material resources, the current stage of the power cable operating sector to outer sheath insulation resistance decline in power cable lines more than take no elimination program. In the face of the current situation of the power cable section of the outer sheath insulation defects, it is necessary to sort out the specific situation of the outer sheath insulation defects, analysis of its continued operation caused by the risk of power cable failure, research power cable outer sheath insulation defects maintenance strategy to improve the reliability of defective power cable operation.

3.2 A two-component sub-polymer resin technology

Insulating materials have a long history of application, with many European countries beginning to research insulating materials as early as the early 20th century, when the main raw material was the high-voltage stator coil, followed by countries such as the United States, which began to join the research into insulating materials, making many types of insulating materials available during this period. The successful development of these insulating materials was the first shot in the history of materials development in China, and since then many insulating technologies have been developed in China. Epoxy resin is exactly the kind of insulating material that emerged from the continuous experimental research of researchers, and its application has an important role in promoting the development of the power industry.

The project uses a two-component sub-polymer resin, a two-component polyurethane resin, coated on metal and rubber parts. This elastic rubber material is suitable for construction where durability, elasticity, abrasion and tear resistance are required. It is easy to mix and apply, requires no specialist tools and cures at room temperature without the need for high temperature work or vulcanisation. It is easy to work with special repairing tools, making it easier and more convenient. This repair material, a two-component sub-polymer resin, is used in a wide range of applications, including cold-curing rubber linings on pump housings and impellers to provide long-lasting impact and wear protection; forming drive couplings for fast turnaround and wear protection; casting new components such as shock absorbers, elastomeric modules and pilot bearings; rebuilding rubber and metal surfaces to provide long-lasting wear resistance; and repairing lobe pumps by casting new cams to their original dimensions, avoiding longer delivery periods and higher costs.

3.3 Technology for special repair tools

Printed electronics has become an advanced electronics manufacturing technology that has emerged in recent years. The principle is to use traditional silk-screening, ink-jet and other means to transfer materials of a conductive, dielectric or semiconductor nature onto a substrate to create electronic devices and systems. It is fast, efficient and flexible, and can form conductive lines and graphics on a variety of substrates of different materials, or even entire printed circuit boards. Combining 3D printing technology with printed electronics is a hot topic of research at the moment. 3D printing technology can be shaped directly and is simple and easy to use. Printed electronics allows for large-area, flexible manufacturing of circuits, which is fast and flexible.

The project involves the repair of broken power cables, the point of breakage is uncertain, the size of the broken power cable is uncertain, so there can be no special unified utensils, need to determine the shape and size of the utensils according to the site of the power cable breakage. 3D printing technology has been developed very mature in the existing technology development of society, 3D printing is a rapid prototyping technology, also known as additive manufacturing, it is a digital model file as the basis, the use of powdered metal or plastic and other bondable materials, by way of layer-by-layer printing to construct the object technology. 3D printing is usually used digital technology material printer to achieve. It is often used to make models in areas such as mould making and industrial design, and is gradually being used for the direct manufacture of some products, with parts already being printed using this technology. The technology is used in jewellery, footwear, industrial design, architecture, engineering and construction (AEC), automotive, aerospace, dental and medical industries, education, GIS, civil engineering, firearms and other areas. The applications are so diverse that 3D printing technology can be used to quickly design and manufacture the specialised tools required for the job, depending on the needs of the site. The most immediate benefits are material savings, the elimination of trimmings, improved material utilisation and cost reductions through the abandonment of production lines; the ability to achieve a high level of precision and complexity, in addition to the ability to represent designs on form curves; the elimination of the need for traditional tools, fixtures and machine tools or any moulds to produce any shape directly from computer graphics data; the ability to automatically, quickly, directly and accurately It can automatically, quickly, directly and precisely transform the design in the computer into a model, or even directly manufacture the part or mould, thus effectively shortening the development cycle of the special tooling and achieving the perfect result of immediate use [1].

4. Broken insulation repair technology based on two-component sub-polymer resin technology

The project proposes a new material application for the repair of damaged power cables, which can be applied to a variety of field environments, involving material analysis, structural design and 3D printing technology. The specific requirements of this power cable repair solution are [2].

(1) Confirmation of the material and properties of the insulation layer of the power cable from the perspective of the operating environment, and selection of the optimum repair material that will better adhere to the substrate, and that the emergency repair solution for damaged power cables can be constructed in any environment.

(2) From the repair material perspective, the two-component polymer resin should be weather resistant, chemically resistant, resistive, resistant to abrasion and impact, and have good adhesion to a variety of substrates.

(3) From the perspective of 3D printing technology requirements, the modification solution can encounter a variety of different site environment required repair tools, to be able to quickly model to print molding, put into use positive response.

The overall structure of the emergency repair programme for damaged power cables is: site survey to confirm the site environment and the state of the damaged power cables; clean up and repair the damaged power cables to order; measure the size and special repair tool modelling 3D printing; prepare the repair materials; and finally carry out on-site construction. The entire phase is rigorous and orderly, achieving the goal of repairing power cables.

The key technologies to be addressed in the emergency repair programme to achieve the above objectives are.

(1) The analysis of the material of the power cable insulation layer

(2) Analysis of the material of the insulation layer of power cables.

(3) Structural design of special tools

Realisation of customised chemical apparatus, perfect fit, making power cables and repair materials to achieve the target effect of the operation.

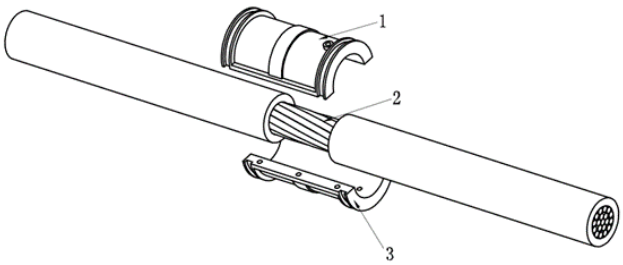
(4) 3D printing technology

To achieve a rapid response to the needs of customised chemical apparatus on site, and to achieve high precision and perfect results.

The key technology in the emergency repair programme for damaged power cables, from a materials science perspective, requires the ability to achieve better adhesion of the two-component polymer resin to the substrate, weather resistance, chemical resistance, good resistance to abrasion, impact and other characteristics in extreme external environments. From the point of view of the structural design of special tools, 3D printing technology is used to achieve a rapid response and a perfect fit to achieve the operational objectives of the repair solution.

As shown above, the power cable was broken outside the emergency repair solution first identified the wire in-

sulation breakage point after the preparation, according to the site environment and construction conditions, measurement of the wire and the preparation of the wire breakage at the fixed design of the repair solution of the exclusive tool structure, modelling and then by 3D printing technology to quickly and accurately produce the repair solution of the exclusive tool, this kind of solution can effectively repair the power cable due to various factors The 3D printing technology is then used to quickly and accurately produce a tool that can effectively repair external damage caused by various factors.



1 - 3D printing technology for custom design of structural parts (upper part);
2 - broken wire insulation (after rectification);
3 - 3D printing technology custom-designed structural part (lower).

Fig. 1. Schematic diagram of the emergency repair solution for damaged power cables.

With the "double carbon" goal and the need for energy transition, the power system is gradually developing in the direction of low carbon and environmental protection. There is a growing interest and research in environmentally friendly electrical materials and equipment, such as the use of recyclable polypropylene instead of non-recyclable cross-linked polyethylene cables. In addition, thermosetting epoxy insulators, which are widely used in GIS, GIL and switchgear, are difficult to recycle directly after retirement and will inevitably cause a lot of environmental pollution and waste of resources. Therefore, research into green and recyclable insulators has become a key issue in supporting the development of insulating components [3].

5. Summary

With the rapid development of society and the improvement of people's living standards, the power system is developing in the direction of extra high voltage and intelligence, and the cable is being more and more widely used with its own advantages of high reliability and good safety factor. During the installation and use of cables, due to external factors and their own ageing, the insulation and sheath materials of cables inevitably produce micro-damage or micro-cracks, and it is difficult to detect minor defects inside the cables with the existing inspection technology. During cable operation, micro-cracks within the insulation material can trigger and accelerate the growth of electrical branches under the action of a continuous electric field, eventually breaking through the insulation material and causing irreparable disaster. In addition, the presence of micro-damage and micro-cracks also degrades the electrical and physical properties of the cable material, seriously affecting the actual service life of the cable, especially for cables buried deep underground and in the deep sea, which are difficult to service and costly to repair, resulting in serious economic losses in the event of an accident. The repair material provides a good idea to solve the micro-damage in the cable insulation and sheathing materials, and is able to self-repair during the damage of the cable, so that the problem of micro-damage and micro-crack in the insulation and sheathing layer can be well solved and has important research value.

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