Cause Analysis and Solutions About Abnormal Heating of Equipment Clamp

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Abstract: As a kind of link terminal in power grid system, clamp has become one of the key components and widely used for connecting the transmission lines and electrical equipment. However, the joint between the tubular structure and the terminal plate or the drainage plate is always a weak part, which is easy to produce defects and then accelerate the failure of the clamp during service. This is also limited the use space of clamp to a certain extent. In this paper, research status on heating causes of equipment clamps and the corresponding solutions are mainly summarized. And the application of disc shape memory alloy gasket as well as the design of mortise tenon structure clamp will fundamentally solve the problem of abnormal heating of wire clamp.

Keywords: Clamp; heating; locked; bolt; memory alloy; mortise tenon.

1. Introduction

Electric power is a basic system of the national economy and the most important part of the energy industry[1-3]. The production of the electric power is a continuous process including power generation, transmission, transformation and distribution, and problems occurred in any link will affect the whole system[4-5]. If these problems cannot be handled in time or reasonably solved, a series of chain reactions will be induced, causing a large-scale power failure of the system and leading to the expansion of the accident. Therefore, it is particularly important to ensure the safe and stable operation of the power system.

2. Importance of equipment clamps

Equipment clamp is a kind of link terminal in power grid system, which is one of the key components and widely used for connecting the transmission lines and electrical equipment [6-7]. The commonly used equipment clamps are divided into aluminum equipment clamps and copper aluminum transition equipment clamps, which are usually composed of the fastening strand part and the electrical equipment connection part. The former is mostly tubular structure, while the latter is terminal plate. In addition, SY type equipment clamp (Fig.1 (a)) is usually produced by welding aluminum pipe and terminal plate or integral casting, and NY type equipment clamp (Fig.1 (b)) is mainly used in power transmission lines and made of aluminum alloy, producing by welding the strain tube and the drain plate [8].

Fig.1 Common types of the equipment clamp

SY type (b)NY type

No matter whether welding or casting is adopted, the joint between the tubular structure and the terminal plate or the drainage plate is always a weak part, which is easy to produce defects and then accelerate the failure of the clamp during service, eventually leading to the interruption of electrical transmission and resulting in a relatively serious power grid accident[9-10]. In serious cases, it may also cause a large-scale power outage, and the resulting national economic losses are incalculable.

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3. Researches on heating causes of equipment clamps

The existing research shows that the temperature of the new clamp will be lower than the conductor temperature during operation. However, the clamp state is deteriorating constantly, when the deterioration reaches a certain degree, the clamp temperature will be higher than the conductor temperature, which will partly restrict the current carrying capacity of the line[11-12]. Therefore, solving this troublesome issue of equipment clamps has become one of the important ways to ensure the normal operation of lines and improve the current carrying capacity. However, at present, the research on different types of joints at home and abroad is mainly focused on the mechanical characteristics. Although some research has been carried out on the overheating problem, while most of them are conducted analysis on individual cases and few researches are provided the operable solutions. The research on overheating of wire clamps is generally attributed to improper installation process, corrosion of wire fittings and the effect of mechanical force [13]. And, there is a lack of systematic research on the mechanism and solution measures of abnormal temperature of wire joints, temperature rise characteristics as well as temperature distribution characteristics. Therefore, there is always a certain blindness in the treatment of wire clamps.

4. Solutions on heating of clamp

The heating of the equipment clamp is mostly caused by the loose connection bolts, the loose contact of the electrical contact surface, and the greatly reduced actual contact area, which leads to the rapid rise of the contact resistance. Therefore, in order to fundamentally reduce the heating of the equipment clamp, it is necessary to reduce the contact resistance of the connector connection during the use of the strain clamp [14]. In the past, when the power equipment has the defects of heating and power failure, method of comprehensive maintenance of power failure is always adopt. The heat of the power equipment is solved by polishing the drain plate, coating conductive paste, fastening bolts, and conducting auxiliary wire shunt [15, 16]. However, these maintenance methods can only temporarily solve the heating problem of the equipment, which belongs to the remedial measures after the event. Moreover, these treatment technologies are outdated, time-consuming and laborious, which cannot effectively reduce the heating fault defects. Therefore, a new type of material or equipment clamp must be developed and selected to increase the contact area at the connection of the drain plate to reduce the contact resistance and effectively prevent the heating fault.

4.1 Memory alloy gasket and its action mechanism

The joint position of the clamp is usually fastened with bolts, which belongs to fixed electrical contact. During the long-term operation of the clamp, the bolt loosens due to the vibration, leading to the change from the initial surface contact to the point contact between the drain plates and the increase of contact resistance. In addition, the small voids formed on the contact surface due to looseness and stagger will lead to metal oxidation, further increasing the contact resistance and causing abnormal heating. Too high temperature rise will lead to premature oxidation and corrosion at the bus connection, leading to the increase of contact resistance again. The increase of contact resistance will further lead to the increase of temperature rise of the drain plate, forming a vicious circle.

The connection will generate abnormal heat when the bolt loosens due to long-term operation. Because the memory alloy gasket has temperature sensitivity and automatic action execution, when the temperature reaches the deformation temperature point of the memory alloy gasket, the memory alloy gasket will change from martensitic state to austenitic state and return to the original state. The memory alloy gasket will produce a large restoring force during deformation, which will increase the pressure between the drainage plates, reducing the contact resistance and the temperature. Thus effectively avoiding the heating failure caused by abnormal temperature rise of the drainage plate contact surface.

Shape memory alloy gasket is made based on the shape memory function of the special alloy. At present, the shape memory alloy gasket is usually saucer shaped and have different diameters and thicknesses. When the memory alloy gasket is installed on the connecting conductor through a nut and a bolt, the gasket is in a flattened state. While, when the contact resistance increases due to the looseness of bolts due to the wind force, the drainage plate starts to heat up. When the temperature of the drain plate rises to the reverse martensitic transformation temperature of the memory alloy gasket, the shape of the gasket begins to recover. The shape recovery makes the bolt and nut compress the conductor with more and more pressure. When the bolt and nut are pressed again, the contact surface of the two conductors will be tightly pressed . Therefore, the shape memory alloy gasket increases the contact area of the joint when heating, effectively reducing the contact resistance and heat resistance of the joint.

Figure 2 shows the state of the disc shape memory alloy gasket after installation, the state in use and the shape recovery after the gasket temperature rises. It can be seen that once the temperature of the drain plate exceeds the martensitic reverse transformation temperature of the memory alloy gasket, the gasket will restore its shape and reimplements the fastening effect of the tension clamp bolt, increasing the contact area and reducing the contact resistance. Thus effectively controlling the heating of the drain plate.

Relevant standards requires that it is defined as a serious defect when the hot spot temperature of the connection between metal parts of clamp is between 90 ℃ and 130 ℃. Therefore, the shape recovery temperature test and identification of memory alloy gasket shall be carried out under laboratory conditions, and appropriate memory alloy gasket could be selected according to the specific heating temperature of the equipment clamp.

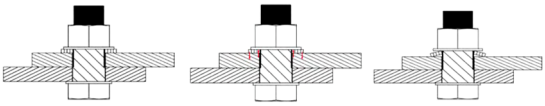

Fig.2 Working principle of disc shape memory alloy gasket

4.2 Structural improvement scheme

To meet the conductivity, the fundamental way to solve the heat problem is to improve the structure of the clamp. The author believes that there are mainly two aspects to improve the structure of the clamp. At first, the bolt connection can be reduced, and the crimping method shall be used as far as possible to avoid the increase of contact surface resistance caused by the loosening of bolts, so as to ensure the temperature rise of the strain clamp within the allowable range. Besides, double contact surface drainage clamp can be designed to increase the conductive area and effectively reduce the heating problem caused by rapid increase of contact resistance due to installation factors or loose bolts. According to the above ideas, clamps such as bolt free hydraulic, spiral, spiral connection and double contact surface drainage are produced as the times require. For new lines, it is appropriate to use bolted hydraulic strain clamp and spiral strain clamp, which can completely solve the hidden danger caused by the deterioration of electrical contact surface. Although the double contact surface drainage strain clamp is superior to the single contact surface drainage clamp, there is still a hidden danger of increased contact resistance. However, The mortise tenon drain plate uses the self-locking function of the dovetail wedge (Figure 7) to closely combine the upper and lower drain plates through the bite force, ensuring that the wire clamp can maintain a good contact state during use, and this connection method can also effectively increase the contact area between the upper and lower drain plates, avoiding the heating defect caused by the use of fastening bolts and their looseness. The author propose another design philosophy which is to combined the upper and lower drainage plates by the bite force from mortise tenon structure, as shown in Fig.3. The wire clamp with this structure can maintain a good contact state during use, and this connection mode can also effectively increase the contact area between the upper and lower drain plates, avoiding the heating defects caused by the use of fastening bolts and their looseness. This special mechanical connection structure can maintain a good contact state during use of the wire clamp, and this connection mode can also effectively increase the contact area between the upper and lower drain plates, avoiding the heating defects caused by the use of fastening bolts and their looseness.

Fig.3 Structure diagram of dovetail type drain plate

5. Inclusion

In general, the fastening effect of the drain plate bolt can be re realized by restoring the shape of memory alloy gasket due to the increase of contact area, the reduction of the contact resistance and the inhibition of the further temperature increase of the clamp, which can fundamentally solves the abnormal heating problem of the equipment clamp. Besides, multi surface contact structure is adopted between the upper and lower drainage plates of bolt free tenon and mortise equipment clamp, which greatly increases the electrical contact area.

The self-locking function of dovetail tenon structure can reduce the use of hot-dip galvanized bolts, improving the anti loose as well as anti galloping performance of equipment clamps and solving the overheating problem of previous clamps in the transmission operation process, which is of great significance to ensure the reliability and safety of substation equipment operation. The development of tenon and mortise type equipment clamp can realized the structural optimization of the drain plate and further improved the conductivity of the drain plate. After further structural optimization, this type of equipment clamp can also be considered to be widely used in power transmission line projects and produce significant economic benefits.

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