Research on detection technology of wire clamp on overhead lines

Rong Liu1, Xiaoli Hu1, Hao Zhang1, Ran Jia1, Yang Zhang1, Chao Zhou1
1State Grid Shandong Electric Power Research Institute, State Grid of China, Jinan, People’s Republic of China
E-mail: 13658649299@126.com

Abstract: Several kinds of widely used detection technology of wire clamp on overhead lines were introduced. Although infrared temperature measurement technology can detect the overheating defects of the clamp, it is difficult to ensure the effectiveness of on-site testing due to the environmental factors, the accuracy of testing instruments, and the experience of test personnel. X-ray inspection technology can accurately measure the exact size of the steel core without damaging the wire, and find the problem of poor crimping of the clamp. According to the field test, the typical clamp defect spectrum of X-ray inspection was listed in this study. It could effectively improve the hydraulic quality detection efficiency of the strain clamp in field work. A method was proposed, to judge the inside corrosion condition of the strain clamp, and to evaluate the current conduction capability, by detecting the current on the clamp and the wire.

1 Introduction

The strain clamp is an important part of the overhead line, which plays an important role in the safe and stable operation of the line [1–3]. The fracture of the strain clamp will directly cause the wire to fall to the ground, and it will be difficult to deal with, and cause a series of serious secondary disasters. Most of the breakage of strain clamp is caused by unpolished or polished not thoroughly of the old wire when the wire clamp is hydraulically compressed. Some operation and maintenance departments installed shunt bar on strain clamp in densely populated areas and important span lines, which can play the role of diversion and reduce heating fault rate of strain clamps.

The wire compressing is a concealed project, and it is difficult to judge whether the process has a problem after the completion of the pressing. At present, the common used detection methods of wire clamp are infrared temperature measurement and X-ray detection. Infrared thermometer can detect the overheating defects of the strain clamp. However, when the shunt bar has been installed on the strain clamp, the current on the clamp with severe defects will be very small or almost zero, so it is impossible to detect defects through infrared temperature measurement for this kind of clamp. X-ray detection [4] can accurately detect the problem of poor crimping of the clamp, mainly in appearance and size, but it cannot detect the internal corrosion. The corrosion inside the wire clamp determines the conduction resistance, which directly affects the conductivity of the current. There is no live detection and evaluation method for the internal corrosion of the strain clamp.

Infrared temperature measurement technology and X-ray detection technology on strain clamp detection were discussed in this paper, and an evaluation method for the strain clamp current conduction capability was presented based on current detection. This method could judge strain clamp internal corrosion situation and accurately know well the clamp’s operation status, in order to make a reasonable maintenance strategy and avoid accidents caused by strain clamp fault.

2 Infrared temperature measurement technology

The defects of the strain clamp are mainly concentrated in the body and the drainage plate, and characterised by overheating. Infrared temperature measurement technology has been widely used on live detection of strain clamp.

In August 2015, a 220 kV line strain clamp was found overheated when detected by infrared temperature measurement. The fault clamp was 65.8°C, while the normal phase clamp was 35°C, and the temperature difference was >30 K. This defect was identified as a serious defect. The fault could not be eliminated in a short time because the line was unable to be cut-off at that time. In September, the clamp was broken at the outlet position, and the wire fell to the ground.

The strain clamp was installed when the line was reformed in June 2011, but the wire was still old wire. During the reconstruction of the line, there was a slight rain, and hydraulic pressing process was not standard. The corrosion was serious on the outer surface of the clamp, as shown in Fig. 1, which led to the increase of the resistance between the wire and the clamp. Finally, a line breaking accident occurred. If some measures had been taken in time after detection, the failure could be avoided.

2.1 Effectiveness

In July 2013, a 220 kV line strain clamp was found overheated by infrared temperature measurement. The fault clamp was 65.8°C, while the normal phase clamp was 35°C, and the temperature difference was >30 K. This defect was identified as a serious defect. The defect could not be eliminated in a short time because the line was unable to be cut-off at that time. In September, the clamp was broken at the outlet position, and the wire fell to the ground.

The strain clamp was installed when the line was reformed in June 2011, but the wire was still old wire. During the reconstruction of the line, there was a slight rain, and hydraulic pressing process was not standard. The corrosion was serious on the outer surface of the clamp, as shown in Fig. 1, which led to the increase of the resistance between the wire and the clamp. Finally, a line breaking accident occurred. If some measures had been taken in time after detection, the failure could be avoided.

2.2 Shortcomings

Sometimes, it is difficult to detect overheated defects of strain clamp accurately by infrared temperature measurement, because of environmental factors, accuracy of testing instruments, and experience of test personnel.

In August 2015, a 220 kV line broken fault occurred due to the overheating of strain clamp. When the fault clamp was installed, the old aluminum wire was polished not thoroughly, so serious internal corrosion occurred after long-time running. Under the condition of heavy load and high current, the steel core overheated, the

The Journal of Engineering

The 14th IET International Conference on AC and DC Power Transmission (ACDC 2018)

J. Eng., 2019, Vol. 2019 Iss. 16, pp. 872-875
This is an open access article published by the IET under the Creative Commons Attribution License
(http://creativecommons.org/licenses/by/3.0/)
mechanical strength reduced, and the wire broken. Before the failure, four infrared detections had been carried out, but no temperature anomalies had been found.

When the load of the line is small, there will be no serious heat on the strain clamp with serious defects, and it is difficult to find the defects by infrared temperature measurement. However, in the special operation mode of power grid, there may be only one line for single power supply because of the power equipment maintenance, and load current of supply line will be greater than in the normal way. If this situation lasts for a long time, it will cause clamp overheating, and result in serious fault.

In July 2012, a 220 kV line tripped due to the wire fell to the ground. When the accident occurred, the temperature was 25°C and the weather condition was condensation. The maximum current of the line was 663 A. The wire surface of the compressing part had not been cleaned up during construction, the wire clamp was unsatisfactory, and the aluminum pipe was not firmly connected. The line was near the seashore, the coal ash field, and the port road. The corrosive medium, like iron ore dust, fly ash dust, and sea fog, entered the connecting pipe from the gap, which aggravated the corrosion of the aluminum wire and the steel core, as shown in Fig. 2, and the mechanical strength decreased after the wire joint, it is not accurate to measure the temperature of the equipment is portable and the image is intuitive. The disadvantage is that it can only detect the location defects of the antiskid tank, but cannot detect other kinds of defect.

X-ray detection is one of the five commonly used non-destructive testing methods, the image is intuitive, and the disadvantage is that it can only detect the location defects of the antiskid tank, but the other types of defects cannot be detected. X-ray detection technology can measure the change of workpiece cross section by measuring the intensity of magnetic field or the change rate of magnetic field intensity. This method can be used to determine the edge of the steel anchor so as to determine the position of the antiskid tank. The advantage is that the equipment is portable and the image is intuitive. The disadvantage is that it can only detect the location defects of the antiskid tank, but the other types of defects cannot be detected.

X-ray digital imaging technology is applied to X-ray detection of wire clamp. X-rays penetrating the detected workpiece can be received by a flat panel detector. The internal crystal circuit of the flat panel detector transforms it into a current signal based on the dose intensity. Finally, it is presented on the terminal computer in the form of digital image [4].

At present, integrated technology has been used on X-ray detection equipment. It integrates the radiographic imaging device, the ray emission device, the radiological wireless control device, the data pre-processing and the wireless transmission system, the power supply battery and so on. Through integration, we need only one device, so the workers can hang the device on the waist as they climb the tower. The worker on the ground can remotely operate the device on the tower and receive the detection data. It is light in weight and can be operated by one person. The detection speed can reach 3 min each clamp. It effectively improves the detection efficiency of the clamp hydraulic quality.

The strain clamp can be divided into four parts, namely, steel anchor pressing area, wire side aluminum pipe pressing area, steel anchor side aluminum pipe pressing area, and aluminum pipe non-pressing area. When the X-ray detection method is used to detect the wire clamp, three positions are usually selected as the measurement points, and the location are shown in Fig. 3. The region labeled ‘A’ is used to check whether the pressing in the concave area meets the requirements. The region labeled ‘B’ is used to detect whether the non-pressing area of the aluminum pipe is pressed. The region labeled ‘C’ is used to check whether the wire meets the requirements. The standard compression image of a strain clamp detected by X-ray is shown in Fig. 4.

### 3.1 Non-destructive testing methods for wire clamp

X-ray detection, ultrasonic testing, and electromagnetic testing have been used for non-destructive testing of wire clamp.

Ultrasonic testing is a non-destructive and rapid detection method based on the principle of thickness measurement. Using ultrasonic testing device to detect the thickness of aluminum bushing, it can indirectly reflect the relative position of aluminum bushing and steel anchor, so as to determine whether there are defects in the location of crimping. The disadvantage of this method is that it can only detect the position of antiskid tank, but cannot detect other kinds of defect.

Using electromagnetic coil to stimulate alternating magnetic field, electromagnetic detection technology can measure the change of workpiece cross section by measuring the intensity of magnetic field or the change rate of magnetic field intensity. This method can be used to determine the edge of the steel anchor so as to determine the position of the antiskid tank. The advantage is that the equipment is portable and the image is intuitive. The disadvantage is that it can only detect the location defects of the antiskid tank, but the other types of defects cannot be detected.
reduce the effective length of the joint, reduce the grip force of the wire, the steel core broken and so on. These defects will directly anchor bottom, the aluminum pipe not tightly connected with the clamp, and greatly shorten the operation life of the clamp [15].

3.3 Typical defect spectrums of X-ray detection

The failure of the strain clamp pressing is mainly due to the over pressure, low pressure, the steel core not inserted into the steel anchor bottom, the aluminum pipe not tightly connected with the wire, the steel core broken and so on. These defects will directly reduce the effective length of the joint, reduce the grip force of the clamp, and greatly shorten the operation life of the clamp [15]. Compared with the standard crimping image, this paper generated the typical defect spectrums detected by X-ray as shown in Fig. 5. In Fig. 5a, 40 mm length aluminum pipe was pressed in non-pressing area, and the pipe was bent, marking as ‘1’. There was 20 mm length not pressed at the end of the wire, marking as ‘2’. The steel anchor groove part was not all pressed by the aluminum pipe, marking as ‘3’. In Fig. 5b, the steel core was not inserted into the bottom of the steel anchor. In Fig. 5c, the aluminum pipe was not tightly compressed with the wire. In Fig. 5d the steel core was fractured.

4 Evaluation method of strain clamp current conduction capability

For the strain clamp on which the shunt bar have been installed, it is impossible to detect the clamp defects through infrared temperature measurement. Therefore, an evaluation method of strain clamp current conduction capability was put forward to judge the internal corrosion of the strain clamp and know well the operation status in this paper. A long type ammeter was used to detect the current of the clamp, the shunt bar, and the wire outside the clamp and the shunt bar. By comparing the distribution of current on the strain clamp and the shunt bar, the current conduction capability of the strain clamp could be judged.

4.1 Evaluation basis

‘Fittings General Technical Requirements’, GB/T 2314-2008, points out: ‘compression fittings resistance between the two ends of wire connections shall not be higher than the wire resistance of the same length’ [16]. Take the 220 kV line as an example, the wire that has been running for >10 years is generally LGJ-300/40 steel core AL stranding wire, and the strain clamp type is NY-300/40. When the shunt bar is installed, the type of the 300/40 AL stranding wire should be chosen. Aluminum sectional area of strain clamp, shunt bar, and old wire, are the same, and steel core sectional area are the same too. The aluminum pipe and wire carry the current. Theoretically, under the condition that the strain clamp is properly compressed, the resistance of the strain clamp and the shunt bar are equal, and the current of the strain clamp is equal to the current of the shunt bar. The current conduction capability of the strain clamp is the best in this case.

Due to the dirt and rust on the surface of the old wire, it is difficult for the worker to polish the wire thoroughly. The conductive grease will also be aging. The longer the running time of the clamp is, the more serious the corrosion and oxidation will appear in the clamp. The more serious the internal corrosion of the strain clamp is, the higher the resistance of the clamp is. The worse the current conduction capacity is, the smaller the current on the clamp is, compared with the shunt bar. When the corrosion of the clamp is serious to a certain extent, the resistance of the clamp will be much higher than that of the shunt bar, and there will be hardly any current passing through the clamp, while the current completely flows through the shunt bar. In this case, the current conduction capacity of the clamp is the worst.

4.2 Determination of early warning value

To what extent the current distribution of the clamp and the shunt bar reaches, what kind of maintenance strategy should be adopted? An early warning value needs to be set. This paper analysed the typical case found on site to set the warning value.

Two strain clamps on phase A and C of a 220 kV line tower were found abnormal heating by infrared temperature detection, the highest temperature reached 160°C, while the clamp temperature on normal phase B was 80°C. It already belonged to a critical defect. The model of the wire was LGJ-300/40, which was put into operation in 1976. The model of strain clamp was NY-300/40, and it was installed in April, 2000. The clamp resistance were measured using a circuit resistance instrument. The three phases of A, B, and C are 633, 152, and 737 μΩ, respectively. The resistance of the overheating clamp was obviously higher than that of the normal clamp. We cut the aluminium-pipe parts of the three strain clamps longitudinally and found that a lot of black grey appeared in the joint area of the aluminum pipe and the wire. The clamp corrosion of phase A and C were obvious more serious than phase B, as shown in Fig. 6. We could see that there was a significant correlation between the corrosion and the resistance value of the clamp.

According to the standard, the DC resistance of 1 m length LGJ-300/40 wire should not be >96 μΩ. In the case above, phase B clamp had been running for 12 years. The corrosion was relatively light and the resistance was ∼1.5 times of that of the wire. It was still running in good condition. The clamp corrosion of phase A and C were serious, and the resistance had been higher than six times of that of the wire, which led to the critical defect.
It can be estimated that for the strain clamp with shunt bar, when the current on the shunt bar is <0.6 times of wire current, i.e. when the clamp resistance is <1.5 times of the shunt bar resistance, the degree of the clamp corrosion is light, and will not affect the operation. When the current on the shunt bar is >0.86 times of the wire current, i.e. the clamp resistance larger than six times of the shunt bar resistance, the clamp has been severely corroded and a potential safety hazard has been existed.

4.3 Maintenance strategy

Based on the above analysis, it is considered that if the current on the shunt bar is > 0.75 times of wire current, i.e. the resistance of the clamp is higher than three times of the shunt bar resistance, measures of patrol and detection should be strengthened. A reasonable maintenance plan should be made according to the change trend of the test results.

If the clamp current is almost zero, a power cut plan should be made immediately, and the clamp must be replaced.

5 Conclusions and suggestions

The overheating defect of the strain clamp can be detected by infrared temperature measurement. However, sometimes the infrared temperature measurement is affected by factors such as the load, background temperature, instrument performance and personnel experience, so the validity of the infrared temperature measurement is difficult to guarantee. Therefore, it is necessary to strengthen the training of infrared temperature measurement methods and requirements to ensure the accuracy of the test results. X-ray non-destructive testing can easily find the crimping defects of strain clamp, but the method requires the line to be cut off. It can be used for the crimping quality control of new strain clamp, and to avoid the unqualified clamp to be placed in service.

In this paper, an evaluation method of strain clamp current conduction capability was proposed for the strain clamp on which the shunt bar had been installed, based on current detection. By using this method, the defects in the clamp can be judged by the way of live detection, the severity of the corrosion inside the clamp can be judged, and the current conduction capability can be evaluated.

The above methods have a marked effect on the detection of strain clamp, but there are some limitations. During the reform of the line, the compressing process should be strictly controlled, and the size and printing should be standardised. The wire before and after the breakpoint should be replaced by new wire as far as possible, especially for important span line, to eliminate hidden danger of line breakage.

6 References

[1] Wu, G., Yuan, Z.: ‘Pressure contact technique for strain clamps used for conductors with large-cross section’, Electr. Power Constr., 2010, 31, (5), pp. 126–129
[2] Feng, A., Jin, R.: ‘Influencing factors of holding force for conductor crimping’, Electr. Power Constr., 2011, 32, (11), pp. 85–88
[3] Hu, J., Liu, C., Ouyang, K., et al.: ‘Analysis on cracking failure of strain clamp on 500 kV DC transmission line’, Electr. Power Constr., 2012, 33, (7), pp. 82–85
[4] Han, G., Wu, Z., Wan, S., et al.: ‘The detection research of high voltage transmission line internal defects based on X-ray digital radiography’, Sci. Technol. Eng., 2015, 15, (3), pp. 227–230
[5] Liu, L., Zou, W., Li, P.: ‘Analysis on 220 kV line clamp failure’, Heat Treatment, 2015, 30, (3), pp. 48–52
[6] Dou, H., Wu, H., Lin, J., et al.: ‘Fracture rule of conductor in clamp by abnormal temperature rising due to strands damage’, Eng. J. Wuhan Univ., 2013, 46, (5), pp. 664–668
[7] Peng, X.: ‘Causation analysis by test and detection on break fault of 220 kV overhead transmission line’, High Volt. Appar., 2011, 41, (2), pp. 354–366
[8] Crinon, E., Evans, J.T.: ‘The effect of surface roughness, oxide film thickness and interfacial sliding on the electrical contact resistance of aluminium’, Mater. Sci. Eng., A, 1998, 242, (1–2), pp. 121–128
[9] Callen, B.W., Johnson, B., King, P., et al.: ‘Environmental degradation of utility power connectors in a harsh environment’, IEEE Trans. Compon. Packag. Technol., 2000, 23, (2), pp. 261–270
[10] Cui, M., Jia, C., Wang, S., et al.: ‘Thermal image characteristic based on poor contact between conductor and clasp’, Jilin Electr. Power, 2013, 41, (6), pp. 36–38
[11] Wang, Z.: ‘Analysis on breakage causes of steel-cored aluminium strands in strained tube’, Electr. Power Constr., 2005, 26, (4), pp. 35–38
[12] Zhan, M.: ‘Running and residual life management for strain clamp of overhead line’. PhD thesis, Hefei University of Technology, 2005
[13] Ying, W., Xu, H., Huang, X.: ‘Analysis of verification for splicing size and mechanical load of overhead conductor strain clamp’, Zhejiang Electr. Power, 2010, 41, (7), pp. 14–16
[14] Lu, Z., Liu, G., Wang, M., et al.: ‘Research on the relationship between steel core and tubes of clamp crimped size and tensile capacity of overhead wires based on X-ray’, Sci. Technol. Eng., 2015, 15, (5), pp. 243–247
[15] Zhu, C., Li, X., Wu, H., et al.: ‘Failure caused by malposition defects and failure simulation of electric transmission line compression fittings’, Corros. Prot., 2015, 36, (4), pp. 373–377
[16] GB/T 2314-2008: ‘Fittings general technical requirements’, 2008