Fault analysis of cement pole and wire in 110kV transmission line

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Abstract. The trip on the 110kV transmission line was caused by the collapse of cement pole and disconnection of wire. A series of tests including macro check, dimensional measurement, mechanical property test and metallographic observation, have been carried out for the failure investigation. The experimental results showed that the failure of #43 pole was caused by combination of the rusting and breakage of transmission line under corrosive conditions and the unqualified hoops cannot bear the impact load and unbalanced tension of broken wires. At the same time, the corresponding supervision measures concerning about the design and purchase of materials used in Grid system and operation and maintenance inspection requirements were also put forward.

1. Introduction

The disconnection of the transmission line or even the collapse of the tower will cause the power supply to be interrupted, which is not in line with the people's desire to enjoy high-quality power supply services[1]. The increasingly harsh atmospheric environment has caused corrosion of steel-cored aluminum stranded wires and fittings[2, 3]. At the same time, icing and strong winds in winter lead to increased load levels on the towers, which are common failure modes of tower line structures[4]. As the predecessors have done a lot of research[1, 5]. In this paper, a on-site investigation, macroscopic inspection, mechanical test, composition and microstructure analysis are carried out for a cement pole sliding door tower structure breakage and inverted pole accident and its failure mechanism is studied, hoping to accumulate experience to provide reference for structural design, operation and maintenance.

2. Experimental Section

The failed cement pole and broken wire were collected from 110kV transmission line in service. The appearance inspection and dimensional measurement were completed on site. The mechanical property test and microscopic observation were carried out in laboratory. The tensile strength and breaking force were measured on a universal tester. The morphologies and structures of the samples were analyzed by metallurgical microscopy (Zeiss microscope).
3. Results and Discussion
In February 2019, some 110kV transmission line tripped between the sections of #43 pole and #44 pole because of the cement pole was collapsed and the transmission line was broken. The transmission line type is LGJ240-40 with the safety factor of 2.5. The ground wire type is GJ-50. LW36-126 circuit breaker spring of some 110kV substation failed resulted from the reduction of travel range. At present, the free height of spring is 358 mm, however, the design free height is 367 mm. The design icing thickness of cement rod and wire structure is 15mm.

3.1. Macro check and dimensional measurement of broken wire

As shown in Figure 1, there is an obvious black covering layer on the surface of the B-phase transmission line. Obvious corrosion has occurred in the steel core at the fracture site, and the steel strand is yellowish-brown with a thinner diameter. The steel core of the aluminum strand which is half a meter away from the wire fracture were also be corroded. The steel strand at the fracture site is embrittlement obviously and can be broken by hand. The condition of A- and C-phase wire breakage is similar to that of B-phase.

The ice thickness of broken transmission line was inspected on site which showed that the ice was uneven with an average thickness of 10mm, as displayed in Figure 2.

The minimum diameter and maximum diameter of steel strand at the fracture site of B-phase transmission line are 1.20mm and 1.90mm respectively, and the average diameter is 1.50mm. It is significantly smaller than the standard requirement of 2.66mm diameter of the steel strand of this type of transmission line. The diameter of the steel strand is reduced by 43.6% due to corrosion. The variation of the wire strand diameter of A-and C-phase fracture part is similar to that of B-phase.

3.2. Macro check of cement pole and electric power fittings
#043 pole is inverted to the direction of smaller serial number, and the roots of both sides have been pulled out of the soil. The left bar was broken into 5 segments, and the right bar was broken into 4 segments with distortion. The left bar was pressed on the right bar, and the specific morphology is shown in Figure 3. The outer layer of the cement pole is weathered to a certain extent, and the internal reinforcement is free from rust.

Detection result of #043 pole B-phase suspension wire clamp indicated that it slipped relatively to the wire after the failure occurred with a relative displacement of 40mm, as shown in Figure 4.
The four pull wires and pull trays of #043 pole were inspected on site. The pull wires were intact and the pull trays were buried in the soil. No loosening or damage was found.

3.3. Mechanical property test
The tensile specimen was taken from the transmission line with a certain distance away from the fracture of B-phase, and its breaking force was 58.56kN. According to the standard of GB/T1179-2017, the calculated breaking force of LGJ240-40 is 83.37kN. Calculation result indicated that the breaking force of the transmission line is 70.24% of the calculated breaking force, which is lower than the 80% requirement of DL/T1424-2015.

3.4. Composition analysis
The content of C in the fracture hoop was detected by a quantitative spectrometer at 0.24%, higher than the maximum requirement of 0.20% of C content for material Q235B in GB/T 700-2006. The data is shown in Table 1.

| Element | Test values/% | Standard requirements/% |
|---------|----------------|------------------------|
| C       | 0.24           | ≤0.20                  |
| Si      | 0.21           | ≤0.35                  |
| Mn      | 0.95           | ≤1.40                  |
| S       | 0.028          | ≤0.045                 |
| P       | 0.031          | ≤0.045                 |

3.5. Metallographic analysis
Metallographic microscopic analysis was carried out on samples taken near the fracture collar fracture, and there were strip inclusions in the tissue, as shown in Figure 5.
3.6. Failure analysis

The design drawings of the spring was checked and it turned out that the material diameter, mid-diameter and free height of the spring are not in conformity with the standard GB/T 1358-2009.

The transmission line of #043 pole at the direction of larger serial number passes directly above the pollution source of mining and chemical enterprises. Due to the corrosion caused by acid pollution environment, the galvanized steel core of the wire is seriously corroded, and its diameter becomes thinner and embrittlement, which leads to the decrease of the overall carrying capacity of the transmission line. Finally, the B-phase wire breaks under the influence of ice covering and wind vibration. At the same time, because of #043 pole arrows on the right side band material and organization is unqualified, with the impact load of B-phase transmission line produced by the fault and fracture under the action of the imbalance of tension, the hoop in the opening part fractured, the right side of the anchor invalidated. Right side of the cement pole of #043 pole collapsed leading to the failure of left side of the concrete pole and line break fault of A- and C-phase.

In addition, the fault also reflected two management problems. Firstly, is the improper selection of anti-corrosion transmission line, high anti-corrosion ability of aluminum alloy wire or aluminum-clad steel and aluminum strand should be chosen in the condition of the acidic corrosion environment instead of ordinary type. Secondly, the line transformation and replacement is not complete which did not replaced the cable hoops with the cables.

4. Conclusions

In consideration of above discussions, this is a typical case of failure in operation due to unqualified materials of hoops and wire corrosion under corrosive conditions. The main reason is that the sudden breakage of transmission line due to severe long-term corrosion in service. The secondary reason is that the unqualified hoop cannot bear the impact load and unbalanced tension of broken wire. To avoid similar failures, various measures about both the design and purchase of materials and operational recommendations were provided.

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