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The Operating Principle and Experiment of the Device for Abandoning Lines to Protect Electric Poles

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At first, it introduced the device used for abandoning lines to protect electric poles from overload in distribution lines. The device set the weak parts in the annular ring, after the deformation of the rings caused by the load, the weak parts moved first, so that the device separated into two parts, finally the electric lines would fall down from the poles. It analyzed the action theory and set up the equivalent experiment to simulate the action process. By the experiment, it shown the reliability of the device in working, and by changing sizes of the annular ring, different action force of the device would be get, so that it could use to protect various levels electric poles.

1. Introduction

At present, when designed the distribution lines under the influence of natural disaster, such as typhoon and icing, it usually took the repeat frequency based on the historical data, and combine the construction cost and transmission capacity of the distribution network lines (Pourahmadi-Nakhli and Safavi, 2011; Yin et al., 2012; Zanini et al., 2016; Xie et al., 2016). This design method had considered all aspects of the factors scientifically, but it could not answer beyond the design conditions of natural disasters. According to situation of the emergency repair missions in the power grid, if the electric poles, instead of lines, armour clamp, porcelain cross arm and based firmware in the distribution network system was intact, the difficulty to repair would decrease, the repair efficiency would improve, the repair cost and time would decline (Wang et al., 1996). So, in order to finish repairing after a disaster more efficiently and provided guaranteed power supply tasks, it had better to protect the electric poles when the typhoon came. Also in this way, the damage of distribution network system would get to minimize (Hizam et al., 2002; Wei et al., 2016).

So, the theory of abandoning lines to protect electric poles came out, which mean that when the distribution network lines suffered from typhoon or some other meteorological disasters, some special links would action first before the poles collapse, so the lines and the poles would separate into two parts uncorrelated, so in this way, the pole had been protected (Xiao et al., 2016). Now the best way to realize this theory was to adopt the device for abandoning lines to protect electric poles. Just as it implied, when the force exceeded the design load, the device would action, which made the weak links form active destruction, so the result was that the lines and the poles separate, finally the function had realized (Xiao et al., 2015; Xie et al., 2014).

In this paper, it designed a device for abandoning lines to protect electric poles from overload in distribution network lines. Shown in Figure 1, (a) illustrated the overall structure of the device, (b) was the enlarged view of the weak links and (c) was the figure of the clamp device fell from the device. In this device, the working process was completed by the annular ring, which was illustrated as part 4 and the cutting-edge shaft, which was illustrated as part 3. When the line (part 2) suffered from the tension on the wire caused by the wind, the load transfer to the cutting edge shaft (part 3) across the suspension clamp (part 1), the step X on the cutting edge shaft would extrude the annular ring, because of the obstruction by the shell (part 5), the annular ring could only expand in the plane which was perpendicular to the central axis of the cutting edge shaft 3, so the cutting edge shaft would move a little distance, where made the davit (part 8) break away from the support surface Y on the cutting edge shaft 3, which was shown in Figure 1 (c). Finally, the line separated from the pole, the action of abandoning lines to protect electric poles had finished.

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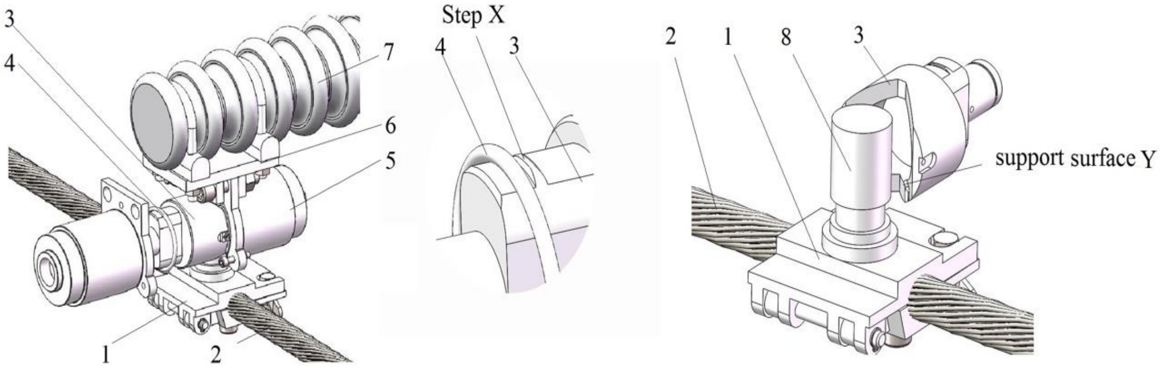


(a) (b) (c)
1. Suspension clamp device 2. Lines 3. Cutting edge shaft 4. Annular ring 5. Shell 6. Adapting piece 7. Porcelain crossarm 8. Davit

Figure 1: Device for abandoning lines to protect electric poles from overload in distribution network lines

2. The stress model analysis of the pole

Assume the factor of the poles and the lines in the network system was the same, and then the most basic unit could be constituted by three pole models and two arbitrary span wires. Usually, the ordinary pole was K lever pole. The theory of three pole model and its stress analysis was detailed discussed in References (Xiao et al., 2014; Zhang et al., 2013), so now it does not go into details in this paper.
Assume the distribution network line was made up with the 12 meters, K lever electric pole, the line span was 50m and the altitude difference was zero, according to the stress calculation formula of pole model, it got different bending moment of the poles with different wires, shown in Table 1, when set the wind speed was 35 m/s.

Table 1: Bending moment of different lines

Line type	JL/G1A-150/25	JL/G1A-185/25	JKLYJ-10/120	JKLYJ-10/150
Bending moment of the pole *M* (kN•m)	20.30	22.37	25.26	27.11

It showed that different kinds of lines had different bending moment, but the general tendency was approach. Set the wind from 20m/s to 50m/s, it got the curve of different bending moments changing with the increasing wind speeds, which was shown in Figure 2.

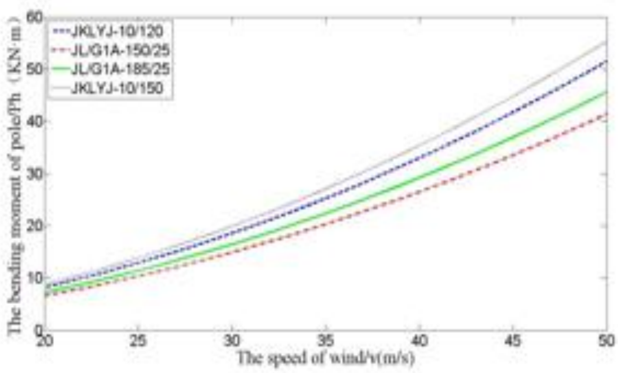


Figure 2: The curve of different bending moments changing with the increasing wind speeds

It showed no matter which kind of lines it was, when the wind speed increased, the bending moment of poles increased, too, and different kinds of lines would have resulted in different bending moment. In this paper, it just chose the line JL/G1A-150/25 to take experiment.

3. The stress analysis of the key components

In the action of the device, it was significant to discuss the process of annular ring going across the step on the cutting-edge shaft, so the paper adopted energy method to analyse this process.
As shown in Figure 3, the annular ring had assembly in the shaft and the chip-off part of the shaft used for the annular ring deforming. Among them, F_O was the force on the annular ring added by the shaft and point to the axis, F_X was horizontal component, F_Y was vertical component, θ was step angle.

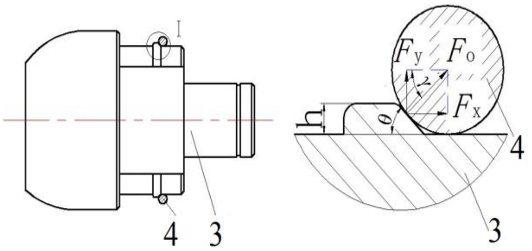


Figure 3: The annular ring going across the step on the cutting-edge shaft,

According to the Bechs Carat theorem in calculating plane deformation and ignore the influence of torsion and shear, it could get the formula,

$$V_\varepsilon = \int_l \frac{F_N^2(x)dx}{2EA} + \int_l \frac{M^2(x)dx}{2EI} \tag{1}$$

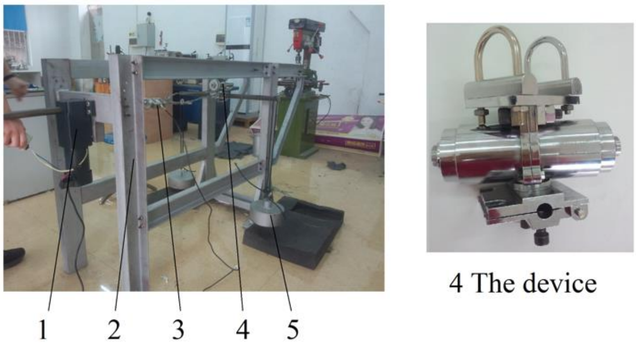
Among them, V_ε was strain energy, J, F_N was axial internal force, N, E was elasticity modulus, pa, A was cross sectional area, m^2, I was moment of inertia, m^4, M was bending moment, N•m.
Therefore, the power caused by the cutting-edge shaft acting on the annular ring was equal to the total strain energy of each point on the ring and the energy dissipations of the friction force. According to Unit Load Method (Brown, 1969; He et al., 2010), it was finished with,

$$F_x \cdot l_x = 4\int_0^{\frac{\pi}{2}} \frac{(F_y \cos\phi)^2}{2EA} d\phi + 4\int_0^{\frac{\pi}{2}} \frac{(F_y R(1-\cos\phi) - F_y R(1-\frac{2}{\pi}))^2}{2EI} d\phi + W_f \tag{2}$$

Where F_X and F_Y was above; I_X was the displacement of the cutting-edge shaft, m; R was the radius of the annular ring, m, W_F was frictional work, J; for the design in this paper, $\theta = 45°$, hence F_X=F_Y. It the kinetic analysis of annular ring going across the step on the cutting-edge shaft.

4. The experimental research of the Device performance

In the actual distribution network line, the 12 meters, K lever electric pole's top diameter was 0.19m and reached a length of 12m. The line span was 50m, so for the line JL/G1A-150/25, as the unit weight was 601 kg/km, so line span with 50m length was about 30.05kg. For this large scene, it was unpractical to construct the same model to make experiment. Therefore, in order to simulate the scene, it chose the equivalent experiment to test the performance of the device.
The equivalent experiment in this paper had made sure that the feature and value was the same as the actual one and had only changed the size. All these changes had little effects on the experimental results or could be neglected. In the experiment, the horizontal channel was equivalent to the pole and the device for abandoning lines to protect electric poles was installed on it. There was a steel rod fit in the device, which was used to hang the mass. The two-mass hang on both sides of the steel rod, equalled to the weight of the lines. The load was added be the linear motor, which output linear motion and pulled the device across a steel rope. This replace the role of the wind load. The concrete implementation method is shown in Figure 4, among it, (a) was the experimental environment and (b) was the graph of the device



1. Linear motor 2. Experimental frame 3. Tension sensor 4. The device for abandoning lines to protect electric poles 5. Mass

Figure 4: The equivalent experiment and the device

When experimented, the operation staff opened the motor switch to add the force on the device, because the tension sensor was located in the straight line between the output shaft of the motor and the suspension clamp device of the device, the value equal to the tension on the device.
The tension sensor could measure the peak value or the random value, sampling rate was 1000 times per second, range from 0-5000N, the overload capacity was about 120%F. S and the accuracy was 0.01 F.S.
In the experiment, the motor was loading and the data read from tension sensor simultaneously, the data displayed on the computer screen until the wire clamp fell off. The phenomenon of the experiment was shown in Figure 4, which was indicated that the device had action.

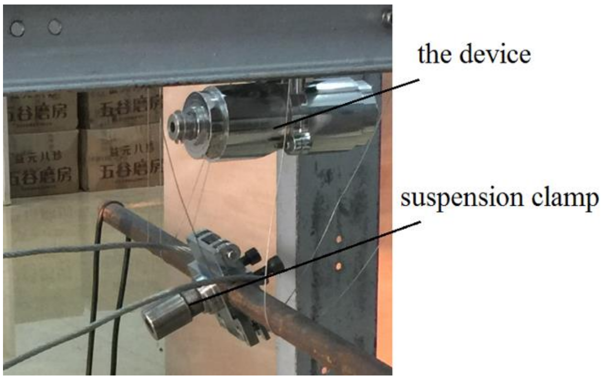
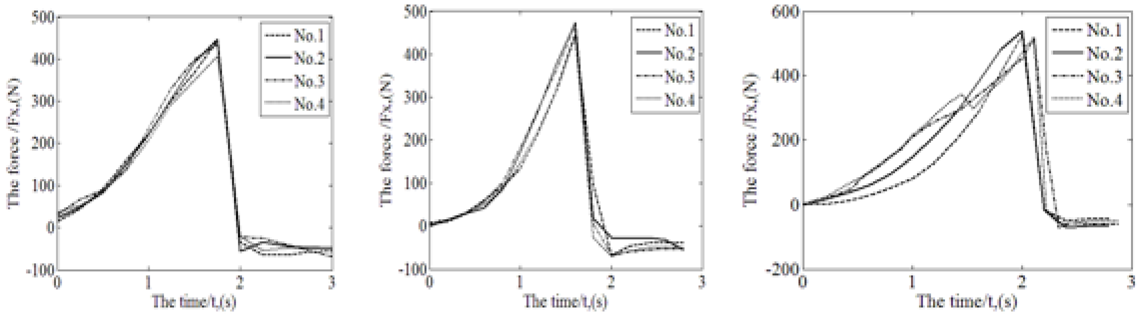


Figure 5: The falling phenomenon

Change the section diameter of the annular ring from 3.2mm to 3.4mm, test the force and do several times to compare the experimental data, all the curve was listed in the following Figure 6 and the action force value were all listed in Form 2, all the annular rings' material was 60Si2Mn.



(a) *d*=3.2mm (b) *d*=3.3mm (c) *d*=3.4mm

Figure 6: The experiment curve

Table 2: The action force value

Section diameter of the annular rings (mm)	*d*=3.2	*d*=3.3	*d*=3.4
Measuring force value (N)	444	447	526
	447	473	538
	433	466	513
	406	442	518
Average value (N)	432.5	457.0	523.75
Theoretical value (N)	422.6	475.1	532.0
Maximum deviation	+2.34%	-3.81%	-1.55%

It could be seen from each curve of Figure 7 that the overall trend of the curve F_x was increased first, decreases after reaching the maximum value immediately, and then kept fluctuant and unstable. The time each curve reaching the peak was just the time the device takes off-line action, which was consistent with the actual desired effect. The needed time of each curve began the loading to reaching the peak was basically close to each other.

In addition, it could be seen from Table 2 that as the diameters of the rings were different, the forces of the devices to take action were also different, but the results were tend to stable, and the maximum deviation value was less than ±5%. It showed that the experimental results are accurate, and as the diameter of the annular ring increased, the action force value increased, too. Therefore, it could adjust the critical condition of the device to take action through designing the section diameter size of annular ring, so that it could be applied to different grades of poles of different lines.

The experiment error came from the manufacture error of the device and the experimental conditions. So it needed to improve the machining precision of the device to improve the accuracy of action value. Furthermore, because of the accuracy limitations of apparatus, it cannot read the maximum value of the force precisely. In conclusion, the action force value, also the off-line value could be got by designing the appropriate diameter of the annular ring, so this device could adapt to protect different levers of poles. What is more, it should improve the precision of the annular ring to improve the action accuracy.

5. Conclusion

The paper came out with a device for abandoning lines to protect electric poles, analysed the influence between the bending moment of poles and the speed of wind, discussed the process of annular ring going across the step on the cutting-edge shaft by energy method and established the equivalent experiment to test action force value of the device. The result showed that the device made good effect in abandoning lines to protect electric poles, and changed the diameter of the annular ring could got different action force. It indicated that different lever poles could be protected by changing the annular ring. Also, improved the precision of the device could got better action effect. This paper made a contribution to protect the poles even the distribution network lines.

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