Birds protection and safety research of transmission lines

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Abstract. Bird related fault of transmission line has become the main factor of line trip. The rule on bird related fault of transmission line is shown in this paper which contains monthly distribution, monthly distribution, reasons of faults and the state of reclosure, the species of related birds, time and season of the faults, environment around the towers, type of towers and insulators and flashover and burns characteristics of the faults. With regard to problems of bird related faults, several anti-bird measures and its characteristics are studied. It is suggested that anti-bird devices should be installed above jumper wires to eliminate the blind area of bird repellent.

1. Statistical analysis on bird related faults of 220kV and above voltage transmission lines

From January 2012 to December 2018, there were 133 faults caused by birds in the transmission line of 220kV and above in a provincial power grid, accounting for 15.72% of the total number of faults. Among all faults caused by birds, there were 125 faults in the 220kV line, accounting for 93.99% of total; there were 8 faults in the 500kV line, accounting for 6.01% of total. From January to December in 2018, there were 17 faults caused by birds in 220kV and above transmission lines, accounting for 16.04% of the total number of faults of the year. The bird related faults were more severe in 2014 and 2015, and the total number of faults was close to 30, accounting for more than 20% of the total number of faults of the year. In the past three years, with the optimization of anti-bird measures and enhancement of management level of operation and maintenance from various units, in the case of continuous improvement of the ecological environment, the bird related fault has shown a downward trend, and the total number of trips has been maintained under 20 times.

1.1. Monthly distribution

Based on the total number of faults caused by birds since January 2012, the number of faults caused by birds per month is normalized to obtain the monthly distribution. As can be seen from the Figure 1, from January to July, the failure rate increased first and then decreased. Among those seven months, the faults caused by birds proved the most severe in March and April, especially accounting for 28.57% in April. Beginning in August, the failure rate showed an upward trend and reached its peak in September. After that, the failure rate decreased and it dropped to the lowest value in December. From the perspective of the whole year, the failure rate tends to be a “double-hump” curve, of which the main peak is in March and April and the secondary peak is in September and October. It is basically consistent with the bird species and its migration characteristics in the region.
1.2. Time distribution
Based on the total number of faults caused by birds since January 2012, the number of faults caused by birds in each period of time is normalized to obtain the time distribution. As can be seen from the Figure 2, the faults might be caused by birds in each period of time, but most of them occurred before noon. Among them, the number of faults proved highest from 5am to 6am, accounting for 43.61% of total. The characteristics of time distribution are closely related to the species and living habits of birds. When the birds have finished eating, the food is digested at night and then defecated, making the flight easier.

1.3. Reasons of faults and the state of reclosure
Since January 2012, most of the faults in this area have been caused by flashover that makes bird droppings shorted to air gaps, accounting for 95.49% of total; besides, there are 6 cases that the material of bird nest short-circuits the line and then trips happen. No trips are caused by dung-contaminated insulator flashover by bird droppings, birds’ short-circuiting the line, and birds’ pecking insulator. Among 6 faults of bird nest, there were 3 cases that the wire dropped from the bird's nest fails the reclosure. The trips caused by other reasons can reclose successfully when reclosing device is put in.

2. The species of involving birds
The line faults caused by bird droppings, nesting, flight and pecking are called bird related faults. They are generally divided into four categories: nests, droppings, short-circuits and birds’ pecking. Among them, the faults of droppings can be divided into dung-contaminated insulator flashover and shorted air gap faults.[1-3]
Faults caused by bird droppings (part of them):

- Kestrel
- Azure-winged Magpie
- Large-billed Crow
- Black-collared Starling
- Upland Buzzard
- Moorhen
- Hoopoe
- Spotted dove

Faults caused by short-circuits (part of them):

- Black Stork
- Oriental White Stork
- White-fronted Goose
- Black-winged Kite

Faults caused by bird nest (part of them):

- Magpie
- Silky Starling
- Long-tailed Shrike
- Grey-capped Greenfinch

Figure 3. Birds related to faults.
Birds cannot store large amounts of feces because of their short rectum. A series of activities, such as nesting, oviposition, brooding, rest and fighting, may be accompanied by defecation in the transmission line tower. When bird defecates near poles and towers, bird droppings might form conductive channels that results in transmission line faults, or be attached to insulators that leads to surface flashover. Birds that cause shorted air gap faults with their droppings usually defecate in the air or at the top of the towers. The amount of their one-time defecation is large, and the droppings are thin and sticky. Just as Figure 3 shows, they are mainly composed of storks, geese and ducks, raptors and other large, carnivorous (fish-eating) birds, including black storks, herons, egrets, greylag goose, bean goose, pelicans, common storks and hawks, etc. Birds that cause dung-contaminated insulator flashover are mainly composed of heron family and stork family of Ciconiiformes and corvidae family, laniidae family and dicruridae family of Passeriformes, including night herons, egrets, magpies, grey magpie, Large-billed Crow, Rook and Black-collared Starling, etc.

The birds’ body reduces the effective insulation distance between phases (poles) or phases (poles) of overhead transmission lines to the ground, leading to air breakdown, which is called short-circuit faults. Those birds which cause short-circuit faults always have large body type with wingspan of more than 1.5 meters, including oriental stork, black stork, egret, heron, duck, black-necked crane and bar-headed goose, etc.

Besides, that birds peck sheds or sheath of insulator might damage composite insulators, and insulators will corrode because of acid, leading to brittle fracture. Those birds that cause pecking faults mainly include magpies and large-billed crow. And there are some birds that might have the same problem, such as grey magpies, rooks, spotted doves, black drongos, white-cheeked starlings, etc.

The faults of nests is that the metal wire and other foreign matters in the nest fall around the lines, resulting in insufficient air insulation distance or surface discharge along the foreign matters. For example, magpie nest is mainly composed of branches, firewood, feathers, mud, wire, plastic sheeting and so on. The wire in the nest significantly increases the probability of short-circuit of lines [4-5].

3. Rule analysis of the faults
According to the statistical analysis, the transmission lines faults caused by birds have the following characteristics:

3.1. Time and season of the faults
Faults of bird droppings usually occur between 04:00 and 06:00, which is related to the fact that birds excrete large amount of excrement before flight. The faults often occur in wet weather, when the air insulation strength is low. Meanwhile, bird droppings lead to insufficient air insulation distance, forming a breakdown discharge. Spring and autumn are the most frequent periods of the faults, mainly from March to April and September to October every year. There are many species and quantity of migrant birds in the season of high incidence of faults, and most of them tend to cause faults of bird droppings.

3.2. Environment around the towers
The poles and towers where the faults occurs are mostly located in areas with wider vision, nearby water sources or rivers, abundant vegetation and food, relatively few human and high elevation. Such areas are conducive to birds' foraging, habitation and reproduction activities.

3.3. Type of towers and insulators
The probability that faults occur in straight towers is higher, the probability that faults occur in type I or II strings is higher, and that of V strings and tension strings is less. However, there have been several bird droppings flashover at jumpers recently, which is related to the lack of anti-bird devices on jumpers. The faults has little to do with insulator material, and the probability of faults on porcelain, glass and composite insulators is basically the same; it has little to do with the type of sheds of
insulator, and the probability of bird damage on large and small shed, double sheds and triple sheds insulators is basically the same.

3.4. Flashover and burns characteristics of the faults
The faults caused by birds generally belong to instantaneous faults with high probability of successfully reclosing. After the faults happen, there are usually obvious burn points on the grading rings and the wires. And there may be burns on the insulator strings, but they will not be distributed on each piece evenly. The flashover obviously whitens the composite insulator; and the down conductor with loose contact has obvious damage points in the contact area between grounding bolt and tower.[6-8]

4. Anti-bird measures and its characteristics

4.1. The bird thorn
When birds land inside the protection area of bird thorn, bird thorn stings the body of birds, prevent birds from staying and other activities in the protection area. Bird thorn has the characteristics of low cost, long life, stable anti-bird effect and large-scale application. It is simple to make, easy to install and has good comprehensive anti-bird effect. Overhead transmission lines of 220 kV and above under the jurisdiction of provincial companies shall be equipped with anti-bird devices. Besides, new lines should be equipped with anti-bird devices before applying, and the installation on existing lines should be combined with power cut. According to the eighteen anti-accident measures of State Grid, the basic protection range of bird droppings flashover of 110 kV, 220 kV and 500 kV suspension insulators is 0.25m, 0.55M and 1.2m circles with the suspension point of insulators as the center, respectively. No clearance between anti-bird devices shall be allowed for bird activities [9].

4.2. Scalable anti-bird needle plate
It can be seen from Figure 4 that the principle of scalable anti-bird needle plate is basically the same as that of the bird thorn, which uses space occupying effect for anti-bird. Riveting is adopted in the whole structure, without welding points. That avoids the steel needle dropping off from the steel plate. The main body is scalable, the size of the protection area can be adjusted by density and length, and the protection has no flaws. The steel needle is made of 304 cold-drawn stainless steel wire. The length of the steel needle is not less than 200 mm. The end of the steel needle is treated for injury prevention. The number of steel needles is not less than 18, the diameter of the steel needle is not less than 2.5 mm. When the distance between the steel needle and the plate is drawn to the maximum, the distance between needles is not more than 70 mm, the length of the steel needle is not more than 140 mm, and the width is not more than 80mm. When the angle between the two substrates is 90 degrees, the length is 500 mm and the width is 60 mm. The overall anti-corrosion performance of the needle plate is enough to pass 168h neural salt-fog test, and no red rust will appear.

Figure 4. Anti-bird needle plate.
4.3. **Insulated anti-bird cone**

Just as Figure 5 shows the principle of insulated anti-bird cone is basically the same as that of the bird thorn. The base is designed with Nd-Fe-B magnet adsorption, which can be directly adsorbed on the cross-arm of the tower. Streamlined taper is used for insulated anti-bird cone to solve the problem of bird thorn that it is easy to be trampled and deformed; strong magnet adsorption was used to solve the problems of fixing and replacing the bird-thorn bolts; reinforced nylon was used to solve the rust and breakage of the bird-thorn metal materials; combined array was used to solve the shortcomings of the bird-thorn combination.

The device has the characteristics of light weight, aging resistance, high strength, good insulation, flexible combination and convenient installation. Strong magnet adsorption can withstand ten-level gale with no displacement, and effectively prevent birds from staying, trampling and sabotaging, and enhance the space for occupation and defense. “Chain-linked” array was used to install the composite board, so as to strengthen the ability of fixing and preventing birds. Small-scale production has begun, and some devices have been equipped in the 510 base tower in Zibo where faults are caused frequently by birds, and they prove effective.

![Figure 5. Insulated anti-bird cone.](image)

4.4. **Acousto-optic bird repellent device of windmill type**

Similar to human eyes, birds have two kinds of photoreceptors in their eyes, rod cells and cone cells. Among them, rod cells contain rhodopsin, which functions under dark vision because of its sensitivity to a small amount of light; cone cells can detect the specific color (or wavelength) of light, so they are particularly important to birds oriented by color; besides, bird eyes are sensitive to red, green and blue light. There are also cone cells sensitive to ultraviolet light. Birds have higher critical flicker frequencies than humans (birds > 100Hz and humans 50-60Hz), which means that they perceive light that is less than or equal to 100Hz or even higher than 100Hz as flickering light. Humans think that flickering light is disgusting, so it can be assumed that birds will do the same. It can be inferred that in this relatively low-frequency light environment, their behavior and reactions should be potentially affected by flickering light, which may even affect their health.

The audio range that birds can perceive is narrower than that of mammals, but birds are very sensitive to distinguishing the intensity of sound and the difference between frequencies. Their ability of distinguishing quick and quasi-continuous sound is 10 times greater than human. Generally, the range of sound frequency that most birds can hear is 40-29 000 Hz, and the most sensitive area is 1000-4 000 Hz.
4.5. Bird repellent device of laser
Birds have little adaptability to 532 nm green laser. Just as Figure 6 shows, intelligent laser emission settings of the device can be programmed to control the random emission of lasers of different time and frequency. It can also effectively reduce the adaptability of birds, and will not lead to device failure due to the adaptation of birds after long-term use. The device is equipped with laser array, which can emit laser of 180 degree and cover a large range [10-11].

![Figure 6. Bird repellent device of laser](image)

4.6. Anti-bird spacer
The spacer consists of two stainless steel plates as shown above. Seen from Figure 7, the material is 8K stainless steel reflective material, which is designed to repel birds by reflecting sunlight. Each stainless steel plate has three cylindrical holes to prevent the device from inletting wind. Besides, the device will shake slightly under the wind, so as to repel birds. The upper part of the two spacers is fixed by three bolts, the lower part is tied to the tower material by four steel belts, and the middle triangle part is just stuck on the V-shaped tower material at the head of the tower, so the fixing is reliable. In May 2017, the devices were installed in 150 base iron towers on 7 lines, such as 220 kV Zaohu and Tenghu lines. Up to now, no bird nest was found in the area where anti-bird spacer is installed.

![Figure 7. Anti-bird spacer.](image)

4.7. Anti-bird device of umbrella type
Seen from Figure 8, the device combines the anti-bird spacer with the bird thorn together, and prevents birds from nesting based on the space occupying effect. At the same time, the needle shape eliminates the shortcomings of the traditional spacer such as blocking wind and sheltering rain. The needle can shake to prevent birds from landing and inhabiting, and the umbrella shape can prevent rain from...
gathering in the middle. There is a drainage hole on the bottom of the device to prevent rain from accumulating, so the device won’t rust because of rain and its service life will increase.

Figure 8. Anti-bird device of umbrella type.

It rotates 360 degrees and is easy to install. It provides enough operating space for the overhaul personnel on the cross arm. Anti-bird device of umbrella type has been widely applied on 220kV lines of Jining Company. No bird nest has been found in the protection area, which shows that the device is effective.

5. Conclusions

Deepen the understanding of bird related fault mechanism and improve the intrinsic safety level of the line. Research shows that the probability of bird droppings flashover on transmission lines in the insulator-centered circle is significantly different. In the design of the size of the insulator anti-bird shield, the opening angle of the bird thorn and the installation position of the spacer, it is necessary to ensure the full coverage of the high-incidence area and strive for the best bird repelling effect of the anti-bird device.

Strengthen the basis of line operation and maintenance, improve the supervision and assessment mechanism, and train the basic skills of line safe operation. Trip because of bird related fault is sporadic, but in general, it is characterized by strong regularity and controllability. Eliminate some employees' misconception that bird related fault is a natural disaster and bird damage can not be prevented.

Define the causes and laws of bird damage, formulate the safeguard measures of operation and maintenance according to time and place, and strengthen the protection of high-risk areas and time. Spring and autumn are the seasons with high incidence of bird related fault in our province. The failure rate presents a "double hump" curve, of which the main peak is in March and April and the secondary peak is in September and October.

Scientifically evaluate the effectiveness of anti-bird measures and adopt cost-effective anti-bird plans. At present, anti-bird measures are changing with each passing day, relevant units of operations and maintenance should timely track anti-bird measures with good effect, simple operation and maintenance, and long service life.

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