Research on Bird Pest Management in Substation Based on Big Data Analysis

Ping Qian[1][a], Donglei Weng[2][b], Yong Zhang[1][c], Guoyi Wang[2][d], Jiang Lin[3,*][e] and Guofu Gao[4][f]

[1]*State Grid Zhejiang Electric Power Co., Ltd., Hangzhou, 310007, China*
[2]*State Grid Zhejiang Electric Power Co., Ltd. Ningbo Power Supply Company, Ningbo, 315000, China*
[3]*Nanjing Desoft Information Technology Development Co., Ltd., Nanjing, 210000, China*
[4]*College of Life Sciences, Nanjing Agricultural University, Nanjing, 210095, China*

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Abstract: For better and more exact management of bird pest in substation based on birds' habits, this paper analyses various bird's data collected from representative substations in Zhejiang Province through data clean, features extraction and data analysis, establishes hazard level for bird species based on estimation of damage caused by birds in substation in Zhejiang Province and proposes measures and suggestions for bird pest management accordingly. The results from sites adopted the strategy demonstrate that, from Jan. 2022 to Sep. 2022, the trip rate of 220kV line was reduced by 80% and the trip rate of 110kV line was reduced by 65%, which obtained good application effect.

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1 INTRODUCTION

Most of the substations are outdoor open type, covering a large area, and are located in plains, hills or mountains with good ecological environment. Bird activities in these areas are relatively frequent, which brings great hidden danger to the safe operation of the substation. At the same time, unattended mode has been widely adopted in substations, which adds some difficulties to bird pest control. In the actual operation of the substation, many equipment failures caused by bird damage have also occurred, and bird damage accidents are showing a growing trend (Chen 2019). However, at present, there is no effective method to effectively prevent birds from entering the substation, which requires us to master the specific situation of bird damage in the substation, so as to formulate practical bird damage prevention measures.

At present, the management and prevention of bird damage in substations are mainly concentrated on the equipment level, such as bird drive devices and bird prevention devices. The literature (Carbonell I 2016) summarized that bird repelling devices include sound, laser, chemical, wind and other types. Through sound, smell, light and other media, they stimulate birds' hearing, vision and taste systems, cause birds to have fear and tension, and worsen birds' living environment, so as to achieve the effect of bird repelling. The literature (Egwumah 2022) points out that bird prevention devices mainly include bird thorn and bird baffle, which are mainly used to destroy the nesting space of birds by installing baffles or bird thorns in the hollows of door frame, gate knife base and other equipment, so as to achieve the goal of bird prevention. Although bird prevention equipment has played a certain role in the application of bird pest prevention, the effect is difficult to meet the expected requirements, mainly because birds have strong adaptability to various bird repellents, and the effect is difficult to continue to be effective (Mori 2021).

In the aspect of bird research involved in the problem of bird pest in substations, the current focus is on the impact of bird behavior on the equipment

[a] https://orcid.org/0000-0002-4937-3479
[b] https://orcid.org/0000-0003-0829-7833
[c] https://orcid.org/0000-0001-6100-170X
[d] https://orcid.org/0000-0002-1309-6625
[e] https://orcid.org/0000-0001-7099-2605
[f] https://orcid.org/0000-0001-9179-7331

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in the substation, while the research on bird species and distribution in substations in different seasons and regions is less, which makes the research and prevention of bird pest in substations less systematic and targeted (Sun 2017). Under the above background, based on big data analysis technology, this paper conducts data mining analysis on the bird species and distribution in the substation, so as to propose targeted prevention and control measures to better strengthen the management of bird pest in the substation.

2 ACQUISITION OF BIRD DATA IN SUBSTATION

Zhejiang Province is located in the south coast of China. Within a year, it will experience weather changes such as fog, plum rain, humidity, rainstorm, typhoon, etc. This climate also makes the substation more prone to bird damage accidents.

2.1 Selection of Substation

In mid June 2021, early July 2021 and late August 2021, a field survey of birds was carried out in 43 substations in Zhejiang Province. The stations cover all cities in the province and are well representative of substations in all regions. The types of substations are shown in Table 1 below:

Table 1: Substation type.

Voltage level	35 kV	110 kV	220 kV	500 kV	1000 kV
Number	4	8	29	1	1

The specific data studied include the environmental data inside and outside the station, the type and quantity statistics of bird species inside and outside the station, and the number and type of bird nests inside the station.

2.2 Collection of Bird Population

The survey time is usually 6:30-10:30 in the morning and 2:00-5:30 in the afternoon. The survey of birds outside the substation is mainly based on the sample line method. Walk around the fence of the substation for 1-1.5km/hr for a week, and record the bird species and number within a distance of about 70m around the substation. The sample point method is used to survey some inconvenient places. The bird survey in the station adopts the combination of sampling line and sampling point to comprehensively record the bird species and quantity on the ground and equipment within the enclosure, and the birds flying over the substation are also included in the station. In order to avoid repeated statistics, individual birds flying in or out of the station from outside will be included in the number of birds in the station and not counted outside the station (Wu 2020). Observation and photographing equipment adopts 8×Binoculars and Canon 7D body, equipped with Shima 150-600mm or Canon 100-400mm lens.

2.3 Collection of Bird Species

During the collection of bird species, 43 substations distributed in various regions were selected to conduct bird nest survey in the station, count the number of bird nests, observe and take photos to record the size, shape, nesting materials and other characteristics of the bird nests, nesting sites, eggs, nestlings and parent birds in and out activities. For the data of transmission line tripping caused by bird damage, the statistics of companies in various cities and regions in Zhejiang Province are used.

3 BIRD PEST MANAGEMENT IN SUBSTATION BASED ON BIG DATA ANALYSIS

3.1 Data Cleaning and Feature Extraction

Data cleaning is a process of finding and eliminating errors or invalid data. When species identification is carried out according to various relevant characteristics of bird nests, many bird nests are not typical due to their attachment to various equipment. The identification of such data should try to combine the characteristics of bird eggs, nestlings and parent birds' activities to improve the accuracy of bird group species data collection. At the same time, image preprocessing and data dimensionality reduction techniques are also needed to extract the key features of bird nests and flocks.

3.1.1 Image Preprocessing

For image preprocessing, the bird nest image is grayed first, and the image in RGB space is converted into a grayscale image. The calculation formula is as follows (1):

$$gray(x,y) = 0.299gR(x,y) + 0.587gG(x,y) + 0.144gB(x,y) \quad (1)$$

Where: $gray(x,y)$ is the gray value, $R(x,y)$,$G(x,y)$ and$B(x,y)$ are the red, green and blue pixel values respectively. The image after gray processing is shown in the following figure.

Figure 1: Image after grayscale processing.

Then gamma correction is carried out. Different correction values γ will make the transformation of gray areas different. If $\gamma < 1$, the gray value of the image can be increased. If $\gamma > 1$, the gray value of the image can be reduced, and the gamma correction processing formula is as follows (2):

$$Y(x,y) = I(x,y)^{\gamma} \quad (2)$$

Where: $Y(x,y)$ is the image after gamma correction processing, $I(x,y)$ is the input image, and the correction value γ can be taken as 0.5.

Finally, the radiation transformation is carried out, and the calculation formula is as follows (3):

$$\begin{bmatrix} u \\ v \end{bmatrix} = \begin{bmatrix} a & b & m \\ c & d & n \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix} \quad (3)$$

Where: x,y are the coordinates in the source two-dimensional coordinate system, and u,v are the coordinates in the transformed coordinate system.

At the same time, edge detection is also required to retain important feature data in the image and reduce the amount of data to be processed, as shown in the following figure:

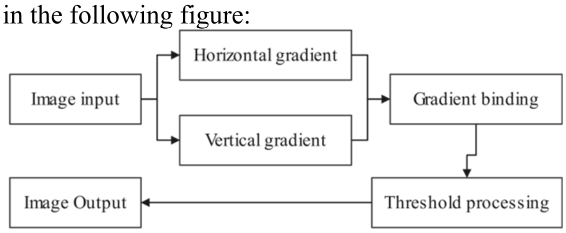

Figure2: Flow chart of edge detection.

After the threshold processing, the image can be clearly displayed, but the image needs to be binarized to reduce the dimension of the pixel matrix and enhance the contour of the bird nest and birds.

3.1.2 Feature Extraction

For the feature extraction of bird flock and bird nest images, this paper mainly adopts the Histogram of Oriented Gradient (Hog). After the image is grayed and gamma corrected, the gradient size and direction of each pixel can be calculated. Sobel horizontal operator [- 1,0,1] and vertical operator [- 1,0,1] T can be used to calculate the gradient and direction of the pixel (x, y) in the x, y direction, as shown in the following equations (4) and (5):

$$G_X(x,y) = I(x+1,y) - I(x-1,y) \quad (4)$$

$$G_Y(x,y) = I(x,y+1) - I(x,y-1) \quad (5)$$

Where: $G_X(x,y)$, $G_Y(x,y)$ are the gradient of the pixel in the horizontal and vertical directions respectively, and $I(x,y)$ are the pixel values of the pixel. The gradient amplitude $G(x,y)$ and direction $\theta(x,y)$ of pixels are shown in the following equations (6) and (7):

$$G(x,y) = \sqrt{G_X^2(x,y) + G_Y^2(x,y)} \quad (6)$$

$$\theta(x,y) = \tan^{-1}\left(\frac{G_Y(x,y)}{G_X(x,y)}\right) \quad (7)$$

Then the histogram channel and overlapping block normalization processing are constructed to obtain the required image features.

3.2 Clustering of Data

After the feature data is extracted, clustering analysis can be carried out according to the feature data. This paper mainly introduces K-means clustering. In this algorithm, set the eigenvector set X of samples as shown in formula (8) below:

$$X = \{X_1, X_2, \cdots, X_n\} \quad (8)$$

In equation (8), X_1 to X_n are the first to nth eigenvectors. For the algorithm step, the first step is the initial classification, so that k=0, and each sample can be regarded as a category, namely:

$$G_i^{(0)} = \{X_i\}(i = 1,2,\cdots,N) \quad (9)$$

The second step is to calculate the distance between various types, on this basis, further generate a symmetric distance matrix:

$$D^{(k)} = (D_{ij})_{m \times m} \quad (10)$$

In the formula, m is the number of categories (m=N at the beginning of calculation). The third step is to find the smallest element in the matrix $D^{(k)}$ obtained in the previous step. Let it be the distance between and. Combine the two categories and into one, and then generate a new clustering $G_i^{(k+1)}, G_j^{(k+1)}, \cdots,$ .Order k=k+1, m=m-1. After the above steps have been completed, it is also necessary to check whether the number of sample categories generated meets the requirements. When the number of categories meets the requirements, the above calculation process can be ended (Yang 2017). At the same time, according to the given data set, K samples were initially selected as the initial center by random method, and then the iterative calculation was carried out step by step according to the principle of the shortest distance. The following figure 3 shows the application of K-means clustering algorithm in the analysis of bird data.

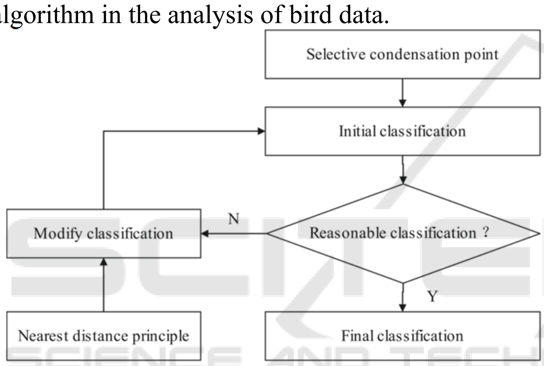

Figure 3: Application of K-means Clustering Algorithm in bird data analysis.

It can be seen from the above figure 3 that in the application process of K-means clustering algorithm, the first step is to select the initial condensation point and carry out the initial classification of bird data, but the abnormal outliers in the sample data should be removed to ensure the accuracy of the sample data. At the same time, the wrong data in the sample should be corrected and verified. Then, if the algorithm program judges that the initial classification is reasonable, it will be the final classification result (Zhang 2019). If the classification of bird data is unreasonable, modify the classification of bird data according to K-means clustering algorithm until the requirements are met, and complete the analysis of bird data characteristics. European distance can be used for evaluation, and the objective function is shown in equation (11) below:

$$J(U, X_{c1}, X_{ci}, \cdots, X_{cn}) = \sum_{i=1}^{n_x} J_i = \sum_{i=1}^{n_c} \sum_{j=1}^{n} u_{ij}^m d_{ij}^2 \quad (11)$$

Where, U is the membership matrix, $u_{ij} \in (0,1)$ representing the membership of the jth sample to the ith category; X_{ci} represents the cluster center of category i, as shown in $J(U, X_{c1}, X_{ci}, \cdots, X_{cn})$; $d_{ij} = \| X_{ci} - X_j \|$ is the Euclidean distance from X_{ci} and j, u_{ij} representing the relative distance between the jth sample feature vector X_j and the cluster center X_{ci} of category i; m is the weighted index (Zhang 2020). By synthesizing the above formula and using the Lagrangian transformation, we can obtain the necessary conditions to minimize the above formula:

$$X_{ci} = \frac{\sum_{j=1}^{n} u_{ij}^m X_i}{\sum_{j=1}^{n} u_{ij\,i}^m} \quad (12)$$

$$u_{ij} = \frac{1}{\sum_{k=1}^{n_c} \left(\frac{d_{ij}}{d_{kj}}\right)^{\frac{2}{m-1}}} \quad (13)$$

3.3 Data Analysis

3.3.1 Analysis Index Selection

When using big data for bird pest management, it is necessary to reasonably select analysis indicators to improve the pertinence of bird pest management, as shown in Figure 4 below:

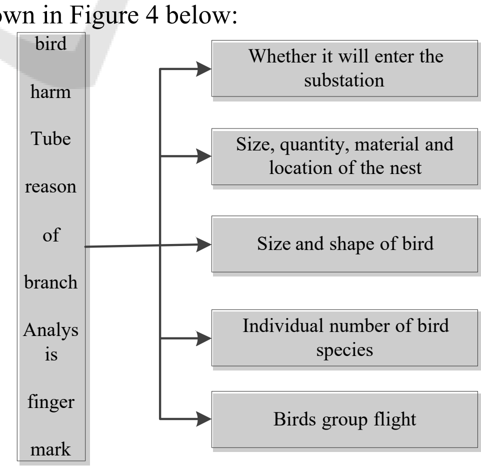

Figure 4: Analysis indicators of bird pest management.

In case of bird damage in the substation, birds need to enter the substation first, and the larger the bird body, the more the bird number, the more the bird nest, and the frequent group flight will increase the probability of bird damage accidents (Zhang 2021).

3.3.2 Species Composition

According to big data analysis, 72 species of birds belonging to 12 orders and 31 families were recorded inside and outside 43 substations in Zhejiang Province. Passeriformes has the largest number of birds, with 42 species belonging to 19 families, while non Passeriformes has 30 species belonging to 12 families. The results by residence type are shown in the following table:

Table 2: Classification results by residence type.

birds	Number of species	percentage /%
resident bird	48	66.67
Summer bird	23	31.94
Winter Migratory Birds	1	1.39

In terms of fauna, there are 31 species (43.05%) in the Oriental realm, 28 species (38.89%) in the widespread realm, and at least 13 species (18.06%) in the Palaearctic realm.

3.3.3 Comparison of Bird Species and Individual Numbers Outside and Inside the Station

A total of 72 species of birds were counted outside the 43 substations and 28 species were counted inside. The maximum number of bird species outside the station is 22, and the minimum number is 5, with an average of 12.58 species per station. There are 11 species with the largest number in the station, and 3 species with the smallest number. The average number of species in each station is 6. The average number of species in the station is 46% of that outside the station.

Through analysis, the number of bird species in different substations is mainly related to the environment, and the substation close to or near the mountain has the most bird species. In addition, there are ponds or ditches and other waters around the substation, and there are many bird species. However, the substation far away from mountains or in plain areas, and the surrounding areas are mainly farmland, has relatively few bird species.

In terms of the number of birds, 5422 birds were counted inside and outside the substation. There are 35 species of birds with less than 5 individuals, accounting for nearly 50% of all species. There are 31 species with more than 10 individuals, and the dominant species with more individuals are Passer montanus, Hirundo rustica, Streptopelia chinensis, Pycnonotus sinensis, Acrothers cristatellus, Turdus merula, Passer rutilans, Egretta garzetta, Motacilla alba, Lonchura punctulata, Sinouthora webbiana, Cyprus daurica, etc. There are 1297 birds recorded in the station, about 1/4 of the total 5422 birds inside and outside the station, and 1/3 of the total 4135 birds outside the station.

The data analysis results show that more than half of the bird species distributed in the substation environment will not enter the station or the probability of entering is very low, which is closely related to the living habits of birds. These species include Gallinula chlopropus, Tachybaptus ruficollis, waders, etc., which have close activities with the water environment, and birds that highly depend on shrubs, arbor forests and other special vegetation activities, such as Sinouthora webbiana, Prinia inornata, Horornis fortipes, Zosterops japonicus, long tailed tits, cuckoos, Babblers, etc. Although some species, such as the brown headed Brucea javanica and dark green hydrangea, have a large number of individuals outside the station, they will not pose a security threat to the equipment in the station.

3.3.4 Analysis of the Hidden Danger of the Bird's Nest

In this study, 359 bird nests were observed on electrical equipment, 329 bird nests were identified, with a recognition rate of 92%. 30 bird nests could not be identified due to incomplete or atypical shape. Table 3 shows the types, numbers and stations of bird nests.

Table 3: Type and quantity of bird nests in substation.

Scientific name	*The number of bird nests*	*The number of substations*	*site of nests*
Streptopelia chinensis	46	13	Knife base
Acridotheres cristatellus	30	12	Knife base
Pica pica	10	4	Longmen frame

Turdus merula	63	16	Knife base
Pycnonotus sinensis	1	1	Area above insulating porcelain bottle
Passer montanus	103	15	Heat shrinkable sleeve, main transformer radiator
Lonchura punctulata	76	5	Main transformer radiator, conservator, heat shrink sleeve, support structure

In this study, 7 species of nests were identified, all of which were resident birds. Among them, sparrows have the most nests and bulbuls have the least. The bird species for nest breeding in the substation are ranked as: Passer montanus, Lonchura punctulata, Turdus merula, Streptopelia chinensis, Acridotheres cristatellus, Pica pica and Pycnonotus sinensis according to the number dominance of nests. The occurrence frequency of each bird species is shown in the following figure:

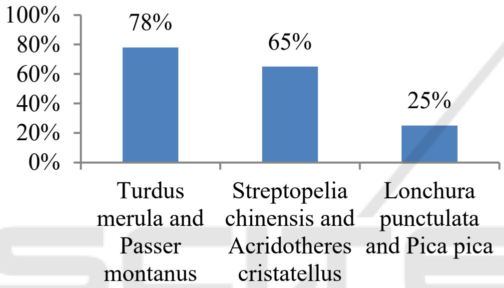

Figure 5: Occurrence frequency of each bird species.

The above nest identification and analysis results show that the hidden danger of bird nests in substations in Zhejiang Province mainly comes from six bird species: Turdus merula, Passer montanus, Streptopelia chinensis, Acridotheres cristatellus, Pica pica and Lonchura punctulata. Nesting birds are common birds in the station, and there is no nesting phenomenon found in many birds such as white wagtail, golden waist swallow, mountain sparrow, brown backed shrike, which is related to the nesting environment and habits of these birds.

3.3.5 Hazard Analysis of Bird Species

Bird hazards include scattering of nest materials, defecation, short circuit of transmission lines caused by flashover during flight, etc. According to the degree of damage, each bird species is divided into 5 hazard levels. Among them, there are 38 types of non hazard level, 16, 9 and 3 types of hazard level 1, 2 and 3, and 2 and 4 types of hazard level 4 and 5, as shown in Figure 6 below:

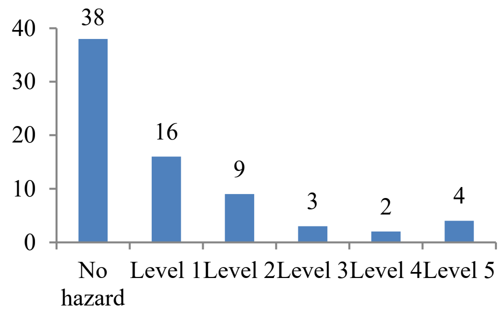

Figure 6: Hazard level of birds.

Among them, Level 4 and Level 5 are the most harmful, including the following 6 bird species: Streptopelia chinensis, Turdus merula, Acridotheres cristatellus, Passer montanus, Pica pica and Lonchura punctulata, all of which are resident birds. Among them, the streptopelia chinensis has a long body and wide wings, and the nest material structure is loose and easy to scatter, so the probability of causing an accident is greater. Most species have low potential hazards, and more than half of birds have no potential hazards to the substation.

4 MEASURES AND SUGGESTIONS FOR BIRD PEST MANAGEMENT

Measures and suggestions for bird pest management mainly includes the following:

1) Placing artificial bird's nests

Build some artificial nests of appropriate size and shape for birds in appropriate areas near the edge of substations or on iron towers outside the substation to induce birds to nest on them reducing and avoiding birds from nesting on other parts of the station. It also helps to reduce birds' activity frequency in the station. This method is mainly aimed at Pica pica.

2) Environmental treatment in the station

Try to reduce the number of plants in the station, timely trim the lawn, weeds and trees. That will reduce birds' activity frequency and the probability

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of nesting and breeding in the station. In autumn and winter, Passer montanus, Acridotheres cristatellus and other birds are easy to group. Reducing the vegetation in the station will help to reduce the probability of accidents caused by birds' group foraging and crossing.

3) Environmental treatment outside the station

The first is to clean up the iron wire and other objects outside the station. The iron wire is often used as nesting material by birds, and it is easy to cause short circuit accidents when falling off on related equipment during flight. Secondly, garbage should be avoided near the substation, and there should be no water source near the substation as far as possible, increasing the difficulty for birds to drink. Finally, trees against the wall should be pruned in time.

4) Design anti-bird-nesting tools

Each station shall reasonably use bird repeller according to the specific situation of bird damage, and the substation far away from the residential area can use tweeter to improve the bird repelling effect. At the same time, the substation management department shall uniformly design and customize various bird stingers and other blocking tools according to the equipment structure and bird nest type of each station to effectively prevent birds from nesting.

A power supply company in Zhejiang Province which has adopted the above comprehensive bird pest prevention management strategy has reduced the 220kV line tripping rate by 80% and the 110kV line tripping rate by 65% during the period from January 2022 to September 2022 resulting good application effect.

5 CONCLUSIONS

This paper combines big data analysis technology with substation bird pest management, aiming to explore the relationship between bird living habits, distribution and bird pest accidents, so that power supply enterprises can take targeted substation bird pest management measures according to the actual situation of local substations. Adopting the method described in this paper in the substation bird pest management can make the bird pest management and prevention more accurate, achieve more effective substation bird pest prevention effect, and ensure the safe and stable operation of substations and transmission lines.

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