An overview of bird related issues in electrical power systems

Ö Polat¹, K Yumak¹, N E Atilla² and M Bağrıyanık³

¹ ÅF Consult, ODTU Teknokent Met Alani, Mustafa Kemal Mah. Dumlupinar Blv. No: 208, D Blok No: 3, 06510, Cankaya, Ankara, Turkey
² Trakya EDCo., 100. Yıl Mahallesi, Barboros Caddesi No: 24 Tekirdag, Turkey
³ Istanbul Technical University, Electrical Engineering Dept., Sariyer, Istanbul, Turkey

E-mail: onder.polat@afconsult.com

Abstract. Power system equipments, especially overhead lines and utility poles are posing great risk to avian species. Main purpose of this paper is to draw attention of distribution companies and community on conserving bird species and their habitats. The paper also provides regulatory framework about protecting bird species, impacts of birds on utility equipments and remedial actions that can be taken for problem specific cases. Furthermore, a sector review of industrial applications and effectiveness of mitigation measures are given. Distribution companies may apply a systematic approach for reducing electrocutions and collisions by developing and implementing Avian Protection Plans (APPs).

1. Introduction
One of the most crucial problems in distribution networks is the bird related outages although they are generally underestimated. Main factors that cause power outages are investigated in Kansas, Manhattan for a five year period (1998-2002) and results show that %19 of the outages is directly related with the animals [1]. Also IEEE has conducted a survey among 114 utility companies and %86 of respondents stated “birds” as the primary source of animal-intrusion outages [2]. Replacement, repair and maintenance cost of damaged equipments, unserved energy and production loss of consumers forces utilities to take proper actions on bird related outages. According to the calculations on economic impacts of wildlife – power line interactions in California, annual cost of animal-related outages is estimated between $32 million - $317 million [3].

Main causes of bird mortalities in power lines can be classified into two categories as electrocutions and collisions [4]. Electrocutions occur when bird touches two different phases of power line or one phase and grounded part, whereas birds not noticing wires and flying directly to them is defined as collision. A quantitative review about bird mortalities indicated that each year 12-64 million birds die at US power lines. Electrocution mortalities is roughly estimated between 0.9-11.6 million and collision victims is approximately in the interval of 8-57 millions [5].

Bird mortalities at power lines has been identified as a problematic issue since 1970s. In each following year this issue drew more attention of utilities, wildlife protection organisations and public. Edison Electric, US Fish and Wildlife Services (USFWS), National Audubon Society and 10 utility companies formed Avian Power Line Interaction Committee (APLIC) to define bird related outages and design mitigation techniques in 1989 [6]. APLIC documents [4,6,7] helped many utility companies create their own Avian Protection Plans (APPs) to minimize bird mortalities thus enhancing system reliability. In addition, IEEE has published two standards; the one is a guideline about reducing bird-
related outages [8] and the other one describes animal related problems in electric power supply substations and explains preventive methods [2].

Moreover, utility equipments are posing risks to endangered species. This issue raises an environmental concern on public and governments. Laws and regulations are enacted to provide protection of migratory and endangered species. For this reason, utility companies are obliged to take corrective actions to avoid punishments and fines.

Having considered environmental and economic benefits, utility companies are encouraged to improve a systematic approach to mitigate bird related outages. Problem solving process starts with fully understanding nature of the problem and determining root causes. Morphological and behavioural inspections on birds must be carried out to choose optimum solution methodology. Energized equipments will be less attractive and dangerous for birds undertaking a series of activities:

- Implementing avian outages reporting system
- Analysis of bird species in researched area
- Looking up for bird related outage mitigation products
- Avian safe designs of utility constructions and equipments
- Scheduled inspection programs focusing on avian safe and retrofitted equipments

In a realistic point of view, there exists no practical solution to keep the birds out from utility constructions permanently because birds are incredibly productive to meet their needs in an exceptional range of area. Intelligent, observant and adaptive capabilities of birds separates them from all other outage cause phenomenas like lightings or switching surges. Therefore, abilities of birds should be taken into account when developing avian safe solution strategies.

In this study, preliminary studies of the R&D project “Bird-related outages in power systems” in Trakya EDCo. are given in a comprehensive manner. The project is financially supported by Turkey Energy Market Regulatory Authority (EMRA). The interaction between birds and power lines are evaluated through regulatory framework, bird-related issues, mitigation techniques and effectiveness of utility applications.

2. Regulatory Framework

Industrialization, global warming, rapidly growing consumption of natural resources and over-hunting diminish population of birds and other species each passing day. Governments regulate their legal system to limit man-kind activities which have negative impacts on the diversity of bird species. However, domestic laws seem inadequate to protect migratory birds because they fly over long distances passing through many countries. Thus, regional and international scaled conventions have signed with the cooperation of governments.

2.1. Migratory Bird Treaty Act (MBTA - 1918)

MBTA is an essential legal basis for conservation and protection of North American migratory birds. It is forbidden to take, hunt, possess, kill, sell, buy, import or export any kind protected birds, their parts, nests or eggs [9]. MBTA has a strict liability statute and has authority to fine individuals (person, corporation, organisation etc.) up to $15,000 and/or up to six months imprisonment for misdemeanour conviction. If the law is knowingly violated then fine raises up to $250,000 and/or up to two year imprisonment can be possible. Moon Lake Electric Association was the first utility company sentenced guilty in the context of MBTA for causing death of 38 raptors and fined $100,000 [10]. After the punishment Moon Lake has agreed to sign MoU and taking necessary steps to prevent bird deaths.

2.2. Bald and Golden Eagle Protection Act (BGEPA – 1940)

BGEPA provides an additional protection to North American eagle species. Utility companies are obliged to meet requirements of BGEPA in the roosting and feeding areas of eagles prior to facilitate any construction activities. Individuals harming eagle species, nest or eggs could be fined up to $100,000 and/or up to one year imprisonment. If the crime is intentional penalties reach $250,000 and/or up to two years imprisonment [11].
2.3. The Endangered Species Act (ESA – 1973)
Primary objective of ESA is to conserve native flora and fauna species that are in danger of extinction or threatened [12]. ESA’s conservation framework also covers habitats of animals and plants.

2.4. International Regulatory Framework on Bird Protection
Apart from the US regulations, birds living in various countries are preserved under legislative work. Regulations includes both protection of birds and their habitat needs. Following agreements are signed in this scope:

- The Birds Directive (1979): European Union (EU) countries published this directive to protect all endangered or threatened species [13]. Directive draws a general outline about how to manage, protect and control the bird population. Any intentional killing, hurting, removal of nests, taking eggs and give disturbance to birds are prohibited. Contracting parties should allocate Special Protection Areas (SPAs) for birds according to this directive.
- The Habitats Directive (1992): EU enacts this directive as a complementary legal support to Birds Directive. It requires Special Area of Conservation (SCAs) sites from member states for species apart from birds. Designated SPAs and SCAs comprise Natura 2000 Network [14].
- Berne Convention (1979): It was the first product generated by international cooperation to ensure conservation of flora and fauna species. Articles of agreement are quite similar with the Birds Directive. Convention principles are applied over a large geographical area because contracting parties are all over the world.
- Convention on International Trade in Endangered Species (CITES - 1975): Specimen of wild animals and plant are separately listed according to vulnerability status. International trade rules (import, export of dead and live animals etc.) of species are regulated with this agreement [15].
- Bonn Convention (1983): It provides a conservation framework in which contracting parties may act to protect migratory birds and their habitats. Birds are categorised in two appendices either as endangered or threatened. Endangered birds are fully protected with strict rules.
- Convention on Biological Diversity (1992): Contracting parties prepared a legal instrument to sustain biological diversity and key components creating diversity and share of genetic resources [16]. It encourages parties to develop projects that will help conserve biological resources. Processes and activities that has possible negative impacts on diversity will be examined via conducting scientific researches.
- Ramsar Convention (1971): Ramsar is an international treaty promising preservation of wetlands with the aid of decisive domestic sanctions and international cooperation. Contracting parties designate at least one ecological sensitive site specifically includes waterbirds.

Turkey has signed following international agreements to conserve bird species and habitats located inside national borders:

- Berne Convention
- CITES
- Convention on Biological Diversity
- Ramsar Convention

3. Bird Related Issues and Mitigation Techniques
Various bird species cause various types of problems in distribution networks. While birds having large wingspans contact directly to phases resulting a short circuit, large flocks of small birds gather on poles and may create both contamination issues and bridging gaps along energized wires. Common bird related problems are as follows:

- Electrocrution Outages
- Bird Collision
- Streamer Outages
Bird Contamination Issues
Nesting Problems
Woodpecker Damage

3.1. Electrocution Outages
Electrocutions occur when a bird simultaneously touches two energized conductors with phase differences or one phase and a grounded equipment. There are several environmental factors contributing to increase electrocution susceptibility:

- Bird species: Large birds such as eagles, hawks and storks tend more to be electrocuted due to their high wrist-wrist distance.
- Age: Juvenile birds lacking of flight control are susceptible to electrocutions.
- Weather Conditions: Dry feather provides insulation up to 70 kV whereas wet feather can only withstand 5-7 kV.
- Seasonal Fluctuation: Utility poles are valuable sit and wait places to look for prey in winter season. In spring time, birds use utility poles to nest and birds rest under the shade of crossarms in summer.

Utility pole configuration extremely impacts electrocution risk beside from environmental factors. Corner poles, double dead end poles and the poles containing energized equipments such as transformer, capacitor or arrester are relatively more dangerous. Bird mortalities due to electrocution can be identified if some of indicators like burn spots, open wounds, burnt feathers and damaged claws are found on carcasses.

General mitigation techniques for electrocution phenomena are summarized below:

- Reconfiguration: Utility pole are redesigned in a manner that it will be avian safe. APLIC recommends 150 cm phase separation for eagle protection. Steel poles with steel crossarms should be avoided because touching only phase will possibly cause birds to be electrocuted. Instead, fiberglass crossarm or wooden pole could be preferred if possible. Also suspension insulators provides a safer platform for birds to roost and decreases electrocution risk.
- Retrofitting with Insulation: Hazardous contact points of utility equipments are coated with insulation materials when adequate separation or other alternative reconfiguration techniques are not achieved. Bushing covers for transformers, arresters or capacitors and insulation of wires are the different kinds of this method.
- Perch Management: Triangle anti perch devices, plastic and metallic spikes and derivatives of these equipments are located on crossarms to prevent birds from roosting. However, if equipments are not placed properly, bird electrocution risk will increase dramatically. Besides, this method only shifts existing problems to other poles of utility so it should be the last choice.

3.2. Bird Collisions
Collisions generally emerge in areas where roosting, nesting and feeding activities of birds are frequent. If overhead lines lie across between feeding and roosting sites then numerous routine flights enhance possibility of collision risk. The thin overhead ground wires are hardly noticed by birds and, mostly birds could not find enough time to change flight direction resulting a collision. Following methods are used to minimize collision events:

- Line orientation: Parallel lines can be clustered so that birds can flyover risky area with just one ascend. Also utility poles may be situated nearby ridges (treelines, hills etc.) which has more visibility for attracting attentions of birds.
- Habitat modification: Habitats of bird species are reorganized to be safer against utility pole threats. Some of the possible measures are; trees having same or higher altitude with the utility poles may be planted, power lines are situated so as not to divide roosting and feeding areas of birds and factors that causes stress in birds are eliminated (shooting, speeding etc.).
Removing shield wire: Occurrence of collision possibility is the highest on overhead ground or shield wire since small radius wires are hardly noticeable for birds. Hence, removing shield wire will dramatically reduce collision events. However, shield wires protects the system against lightning strokes so this application may not be feasible where lighting strokes are intensive.

Burying power lines: Although burying lines is the most precise solution, technical and economic constraints may hamper implantation of this method.

Power line marking devices: Birds can react earlier if they notice power line before coming too close. For this purpose there exists some devices to make lines thicker, colourful and somehow more distinguishable. Main devices are in use are; aerial marker spheres, spiral vibration dampers, flight diverters and bird flappers.

3.3. Nesting Issues

Birds prefer utility poles to mate and raise their youngs in the absence of natural nesting sites. Nest size and position on the poles differ with respect to specimen of the birds. White stork (Ciconia ciconia) is one of the most important stick nest builder on transmission and distribution poles predominantly in Europe. A white stork nested on low voltage tangent pole in Trakya region is shown in figure 1.

![Figure 1. Ciconia ciconia nest.](image)

Nesting create outages in various types of ways:

- Birds drop materials and preys which may contact energized equipments when they take off and land to their nests,
- Nests attract predators and animals climbing over top of utility poles,
- Bird feces accumulating on insulators cause flashovers

It has been recorded that monk parakeet nests caused 198 outages and as a result 10,000 consumers are left unsupplied in South Florida in 2001 [17].

Removing bird nests generally do not provide a permanent solution because most species have instincts to conserve its habitat and they will reconstruct in place of removed area. Moreover, companies can be confronted with large fines unless nest removal permits are taken. Applicable solution methods to overcome nesting issues are given below:

- Installing alternative nest poles,
- Artificial nesting platforms on top of utility poles ensuring necessary electrical safety clearances
- Perching discourages such as triangle anti perch devices, plastic spikes or micro electrical shock systems,
- Placing stick deflectors to bounces off nest materials.
3.4. Streamer Outages
One of the experienced problems with raptors is the streamer outages. Raptors perched on utility poles commonly drops feces before taking off. Feces are mixed with highly conductive uric acid which could partially or completely bridges the distance between conductors. This leads flashovers ending up serious bird injuries or mortalities and outages. Classifying an outage as “streamer” do not always reflect the reality since detection of this kind of problem is not easy. Some of the following clues can be tracked down for investigations of streamer outages:

- Existence of large birds in the region such as eagles, herons and ospreys.
- Outages recorded in 23:00 – 06:00 times of interval [18].
- Food-rich areas like agricultural fields or wetlands.
- Successful reclosing actions after overcurrent relay trip.
- Insulators having burn spots on a few disks of strings which are close to live ends.

134 streamer outages were recorded in China’s transmission system in 2004 and each year estimated financial loss is about millions of dollars [19]. Perching discouragers are widely preferred to diminish streamer outages whereas insulator shields or alternative tower configurations are other applicable choices.

3.5. Bird Contamination
Birds perching on utility equipments leave their droppings onto insulators and accumulation of excrements lower surface resistivity of insulators which can cause outages. Highly conductive humid feces create arc-flash hazards even in nominal voltage ratings. On the contrary of streamer outage that can only be induced by large bodied birds, bird contamination issue could be generated by both large bodied birds and large flocks of small birds.

Perching discourages are not always the best option to avoid from contamination issue since discourages made up for large bodied birds may not be effective against small birds and vica versa. Therefore, insulator shields presents a more generic solution compared to discouragers. Additional shield weight attached to structure must be calculated and periodic cleaning of shield needs to be performed. Sudden flashovers related to bird contamination typically appear in short or long term. Hence, periodic cleaning of insulators are beneficial to maintain insulation resistance. IEEE Std. 957-2005 [20] gives methodology regarding to maintenance of ceramic and non-ceramic insulators.

If an outage occurs when thousands of birds perch together over a night, there is little to do to prevent such a unique case.

3.6. Woodpecker Damage
Woodpeckers drill holes in utility poles aiming to find insect, produce nest cavities to feed their youngs and also drums to attract females for breeding. These rituals speed up degradation of wood strength and decreases pole’s lifespan substantially. Besides holes around crossarms may cause instant outages. Thus, cost of woodpecker damage to utilities reaches millions of dollars in each year. Especially in North America where wooden poles and woodpeckers are sharing the same habitat, distribution companies encounter severe financial and labour force losses. An American utility company spent 385.000$ to repair and replace the 100 poles damaged by woodpeckers [21]. Damage size depends on several factors such as; habitat availability, pole configuration, woodpecker species and insect population.

Applying wire mesh to poles is the common and effective solution in order to reduce woodpecker damage. Artificial cavities are not a promising approach because cavity creating is an important component of breeding activities. Ultrasonic devices are generally inefficient to deter birds from utility poles as the most birds do not hear high frequencies and even if they hear after a period of time they habituate the voice. However, a state of art sonic mitigation device called “Sonic Dissuader” [22] is designed specifically to scare woodpecker out from poles using alarm signals of woodpecker species. Device is only activated by the detection of vibration frequency created with pecking activity so that habituation may be prevented. Test result show that alarm signals did not change time birds spending on pole though they froze right after hearing the alarm call.
4. Sector Review
Utility companies can be separated into two groups considering their perspectives to deal with bird related outages. First group cope with the issue professionally by employing avian reporting systems in which electrocuted birds are recorded with pole numbers, locations and pole configurations. These companies give adequate training to field personnel about what to do when faced with bird mortalities or injuries and how to report these events. Data gathered from the field are transferred to a database and evaluated for determining the poles to be retrofitted. Retrofitting techniques are then checked according to their effectiveness. Second group generally does not have a systematic corporate policy and avian reporting systems, they only retrofit hazardous poles based on field experience also follow up controls of retrofitted poles are not executed.

APLIC recommends utility companies to develop and implement APP. Many companies mostly located in USA and Canada have established their APP [23-28] aiming to; reduce utility related bird mortalities, decrease unserved energy cost, diminish repair and replacement cost of utility equipments and ensure legal compliances.

APLIC gives a general outline scheme of reducing bird related outages risk in figure 2 that can be used by the utilities.

![Risk reduction plan](image)

**Figure 2.** Risk reduction plan [7].

Roles of different type of measures in the risk reduction plan are briefly explained below:

- Preventive measures include designing new and reconfigured constructions so as to be avian safe. Providing 150 cm phase-phase clearance between conductors, using suspended insulators, and utilizing crossarms made of non-conductive materials are the examples of this kind.
- Reactive measures are defined as reporting bird mortalities and risky nests to retrofit hazardous poles and lines. Insulation covers, perching discouragers and line marking devices can be applied.
- Proactive measures cover risk assessment and providing sources to train and increases awareness of operation and maintenance staff of the company.

Transmission and distribution companies which have taken mitigation measures obtained effective results in the aspect of reducing bird mortalities and outages. The results of industrial applications are summarized in Table 1.
Table 1. Industrial applications and effectiveness of mitigation measures

| Company                  | Mitigation Measure                                                                 | Result                                                                 |
|--------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------|
| National Grid (USA) [29] | 500 steel poles are retrofitted using insulation covers and plastic perching discouragers | Annual average outages decreased by %80.                               |
| Seattle City Light (USA) [28] | Nesting platforms were situated on utility structures, new and reconfigured structures are designed with avian-safe clearances. | Bird deaths has diminished by %53 over a 20 year period.               |
| Eskom (South Africa) [30] | 360 transmission poles were retrofitted by 7800 bird guards                        | Voltage dip cost of $3,26 million is saved.                            |
| RWE (Germany) [31]       | 13,000 bird flappers installed on earth wires.                                      | %90 reduction in bird collision rate.                                  |

5. Conclusions

Since many bird species are threatened and faced with extinction, bird related outages have a distinguishing environmental importance compared to other types of faults in power systems. Universities, experts, governmental and non-governmental organizations have been working on reducing bird related outages since 1970s. However, annual electrocution and collision rates still seem to be high because most of the distribution companies do not have a systematic approach to deal with the issue. It is critically important to implement an avian outage reporting system and examine bird fauna in the area prior to implementations of mitigation products and designing avian safe equipments. Hence, distribution companies need to develop and implement their own site-specific avian protection plans to reduce bird mortalities as enhancing service reliability. APLIC guidelines are the key resources for a holistic approach in the development of APPs. However, the studies on each APP should be evolved to meet the particular needs of the power system service area. Taking preventive, reactive and proactive measures will not only provide cost savings also raise a public awareness.

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