



Environmental Impact of Insulators and High Voltage Lines on Birds Flight and Power Interruptions at Tatapur Feeder: A Case Study

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ABSTRACT

The impact of electric energy transfers from power plants generation to substations then to consumers and its own environment is tremendous. Among various hazards, the overhead wires associated with power lines are the most fatal hazard to birds. The power lines and poles have caused fatal risks for birds and have affected their habitats significantly. Dangerous types of power poles in the middle voltage lines which have small distances between the lines and short insulators cause short-circuits between conductor wires or ground-faults. This paper presents a survey conducted in Multan city, Pakistan. In this survey, all 132kV high voltage grids and their 11kV outgoing feeders are observed and their locations are also marked on Google map. This survey includes current construction type of power lines and poles, principles for bird safety, photographic records, public views about deadly poles and Ultraviolet vision in Birds. This study also highlights the cause of bird casualties on high and large scale from overhead power lines. It presents different technical solutions for bird safety such as proper adjustments to the routing of the power lines and power pole constructions can effectively reduce the risks posed to birds. Detailed study is recommended on large scale; so that conservation measures can be suggested for reduction of losses on birds by power stations in Pakistan.

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Authors' Contribution

FU conceived and designed the study. SK wrote the article. MS executed the experiment. FU and SK analysed the data. FU, SK and MS, interpreted the data.

Key words

Hazards to birds, Short insulators, Power interruptions, Photographic record, Bird casualties, Technical solution, Bird safety, Environmental impact

INTRODUCTION

Electrical energy is transferred to consumers through transmission lines. High voltage power lines are mostly above ground. There are mainly two types of electrical faults, symmetrical and unsymmetrical faults. External risks are lightning, wind speed, weather, climate change, bird damage etc. (Wang *et al.*, 2015). The surface power lines increase the fatality rate of open habitat birds by collision and perching sites. There are various factors which influence the risks on lives of birds such as species specific morphology and biology, landscape and topography, weather, technical aspects and spacing of conductors (Shaw, 2013). Different technical solutions for

bird safety are available but electric utility companies are usually unaware of these (Haas *et al.*, 2003; Rybanic, 2007). Some of the reasons behind the faults of power lines are insulation failure, overvoltage, under frequency, reversal of power and stability fall etc. So it is important to check on the line fault to ensure the safety of power lines and environmental factors such as weather and suitable land should be taken into consideration in the course of construction (Haas *et al.*, 2003; Wang *et al.*, 2015). Seasonal birds suffer considerable destruction from structures that are constructed to provide services and amenities to the public. Three of such entities which are growing publicly are communication towers, power lines, and wind turbines. The issues studied in this paper are regarding the structure location, lighting, technical support, lattice or tubular structures, bird's nature, and habitat adaptations (Manville, 2005).

Electrocution hurts mostly the birds which have ground contact. These casualties happen particularly on poorly designed medium voltage power poles (Gyimesi *et al.*, 2010; Nipkow, 2011). The risky power poles in the middle voltage lines which have small distances between the lines and short insulators cause short-circuits between conductor wires or ground-faults. Birds that perch or nest

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on steel lattice towers can be electrocuted by causing a short circuit, either by touching two live wires, or a live and an earthed component (Shobrak, 2012; Shaw, 2013). Three interrelated factors are the cause of bird electrocutions on power lines; biology, environment and engineering. The biological and environmental factor includes size of the body, habitat, prey, nature, age, season and weather. Birds become liable to electrocution due to their nesting, courtship and territorial behavior (APLIC, 2006). There may be causalities due to electrocution where horizontal gap is lower than the wrist to wrist distance of a bird's wingspan or where vertical gap is less than a bird's height from head to foot (APLIC, 2006). These fatalities are not only a preservation issue, but it also causes financial losses due to the power interruptions and repairs. In order to minimize the effect of power lines, these issues must be heightened at the level of environmental agencies and electricity and energy companies (Shobrak, 2012). Many countries that have performed surveys to get statistics of dead birds due to electrocution include Saudi Arabia, Subalpine area in Buskerud Southern Norway, and Central Kazakhstan (Shobrak, 2012; Bevanger and Broseth, 2004; Voronova *et al.*, 2012).

Most collisions occur between huge terrestrial and wetland birds and some smaller, speedy species and overhead wires associated with power infrastructure (Andrew *et al.*, 2010). On power lines, bird collisions are often concentrated along relatively short sections where several factors interact to create a collision problem or 'hotspot'. The combining factors that create a hotspot may not always be apparent (Shaw, 2013). High bird losses occur due to the risks of ordinarily developed medium voltage power poles. These dangerous poles need to change according to recognized technical standards as mentioned in research (Bevanger and Broseth, 2004; Rybanic, 2007) and Voronova *et al.* (2012) that are safe for birds. In case of collision, birds crash with power lines while in high speed. The birds flying during night time are particularly at risk due to limited maneuverability. Apparently birds collide with lines due to limited visibility, that's why they can't escape the collision or impact of falling and suffer terrible injuries. Birds often struck to the non-conducting ground wires which intercept lightning strikes and prevent power outages (Stehn and Wassenich, 2008). Bird collision can still be managed after the power lines have been built by using the data of previous collisions, topography, vegetation and land use to anticipate the undetected high risk sections of line (Andrew *et al.*, 2010). Based on literature (Rybanic, 2007) the most cost effective and attainable way to reduce collision is by maximizing the visibility of power lines by installing markers. Marking devices include aviation marker balls, spiral vibration dampers, air flow spoilers,

bird flight diverters of various designs and dimension, and other devices with movement such as swinging plates or flappers. Different factors such as price and durability must be calculated in order to determine the best marker (Janss and Ferrer, 1998). There are also many researches available that showed by using Ultraviolet lights, the collision of birds may be minimized as described in Bischof *et al.* (2011) and May *et al.* (2017) A detailed study carried out by Douglas and Jeffery (2014) confirmed that the discharges of UV rays on power lines happened as standing corona adjacent to cables and random flashes on insulator and this discharge spectrum (200nm-400nm) was below the standard lower limit of human vision.

MATERIALS AND METHODS

A survey has been conducted on overhead line conductors, construction criteria for bird safety, and detection of dangerous poles which cause bird casualties at "132kV/11kV Grid Station Vehari road Multan and its 11kV Feeder Tata-Pur Pakistan. This substation includes three power transformers and each has a rating of 40MVA. With the coordination of Grid staff and Line workers, we started our survey from the main substation where we inspected all incoming 132kV lines and then we moved towards 11kV feeder Tata-Pur. The total length of this feeder is 60km and it starts from the city area then goes to village side. The 60% of the line passes through farms and rivers. We divided our work in three portions and in each part we decided to cover almost 20km area in order to collect detailed information from local residents and to analyze construction design of power poles. The first part of our survey area included public transport, houses and communication lines. In second and third, it passed through river and farms. We collected all information through inspection of line, design of poles, type of surrounding birds and their causalities. We collected information from farm owners, workers and local residents in order to detect common faults on these lines. In our survey of this feeder, we also investigated the population of local birds, location of their nests, nearby nests from power lines and safe areas. This survey will be most helpful for Bird Conservation Organizations and Wild Life Organizations as they are responsible for the protection, safety and welfare of these birds.

RESULTS

Types of cables and overhead conductors

Control cables are used for AC/DC panels, protection, relay panels, breaker panels, auxiliary panels etc. These are available in different sizes as 2core, 4core, 12core and

16core. The types of cables which are used in grid station to 11kV feeder are given in Table I.

Table I. Type of cables used in grid station to 11kV feeder.

Area	Type of cable (ACSR)	Section (mm ²)		Current carrying capacity (A)
		Total	Al	
Power transformer to incoming panel	954 MCM	498.1	484.6	1095
	477 MCM	280.8	241.6	715
Outgoing panel to pole terminal	4/0 AWG	125.09	107.2	390
	2*4/0 AWG	250.18	214.4	780

Table II. Type of conductors.

Conductor capacity	Rail	Osprey	Lynx	Coyote	Dog	Rabbit
	989A	710A	540A	445A	340A	230A

Power lines from grid station to consumers or to other grid station/s are overhead lines. For the transmission of electricity ACSR conductors are used rather than power cables because the weight and cost will be not effective. Various types of conductors which are generally used are given in Table II.

Rail and Lynx are used for 220kV and 132kV transmission lines. Osprey, Dog and Rabbit are used for 11kV lines. These all are Aluminum Conductors Steel Reinforced (ACSR). For distribution lines 440V and 220V all aluminum conductors (AAC) are used.

Construction criteria for bird safety

Complete data were collected about the installation criteria of overhead transmission lines.

High voltage line 132kV

Transmission line should maintain required clearance to ground. In 132kV lines, the height of conductor which is attached to a support carrying a line conductor is 75-85ft. This distance can exceed due to river crossing, railway crossing or line crossing by using extension of 10-20ft. The clearance between phases is kept 10-12ft and distance between 132kV tower to tower is 320 meter which can be increased or decreased as required. In high voltage lines suspension insulators are used between tower and conductor and several insulators are joined in series to construct a string. The line conductor is carried by the bottom most insulator. Each insulator of a suspension string is called disc insulator. There are nine discs used for 132kV line, a single disc for the normal voltage strength 11kV (Higher voltage rating 15kV). The size of one disc

is almost six inches so the distance between terminal pole and conductor is almost 54 inches or 4.5 feet. The discs of strain insulators in running line are used in vertical plane as shown in Figure 1A and it is used in horizontal plane at dead end of tower (where a conductor length is finished and a jumper is used to connect this end of conductor to other side of the tower) as shown in Figure 1B.

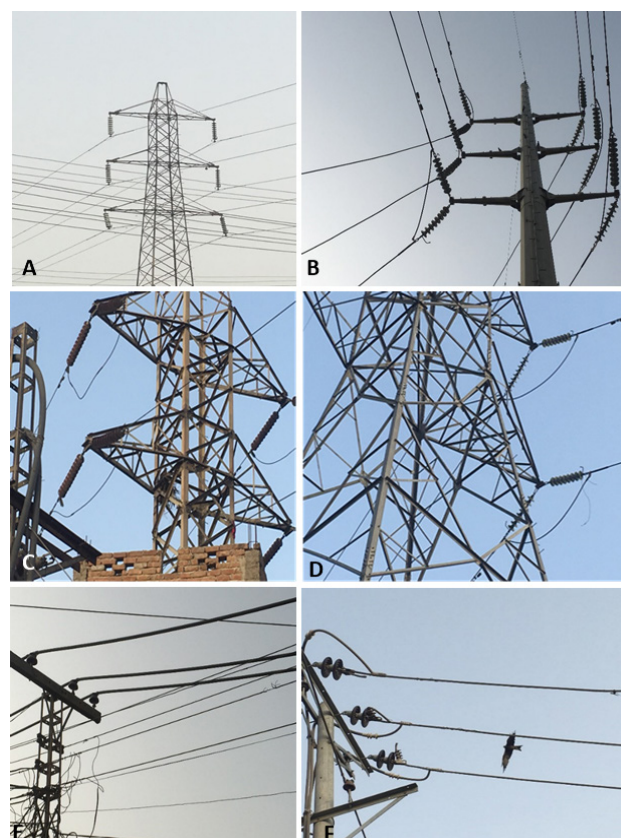


Fig. 1. 132kV Line vertical plane insulators (A), horizontal plane insulators (B), prey black kite nest on 132kV tower (C), A suspended wire on 132kV line (D), pin insulator on 11kV line (E) and disc insulator on 11kV with Jumper.

Faults on 132kV line

Most common bird which is found dead near 132kV tower is paryah or black kite *Milvus migrans*. It is a medium size bird of prey belonging to the family Accipitridae. The maximum size of this bird is 55-66cm or almost 2 feet. There are very few chances of electrocution as the size of the bird is very small as compared to distance between tower and conductor (4.5 feet). The fatality of this bird may occur while they are sitting in groups on insulator discs. Mostly birds use this tower for nesting or perching sites as shown in Figure 1C. The type of fault which is commonly observed on 132kV line is due to clutch wire of

vehicles. Birds take this clutch wire in mouth from ground to tower for their nesting or any other purpose and it can fall on conductors which becomes the reason of fault. A suspended wire on 132kV line can be seen in [Figure 1D](#) which is going from “132kV Grid Station Vehari road Multan” to “132kV Grid Station Qasim Bagh Multan” Pakistan. This suspended wire can touch with the tower in heavy storm and become the cause of tripping. The name of these two lines on this 132kV tower is VHR3 and VHR4. Individual small birds may not be at risk of the conductor to conductor contact that may not pose danger for small birds, however they cannot be safe from electrocution on transformers or other unprotected equipment where separations between energized and grounded hardware are considerably small. Birds may try to pick out insects from inside the covers of poles where protective coverings have been installed on transformer bushings, arresters.

Medium voltage line 11kV

In 11kV feeder, the minimum ground clearance is 26 feet and the length of cross arm which may be steel or wood is 8feet. It means that the distance between phase to phase on 11kV lines can be 2.5-3 feet. Here two types of insulators are used, pin type and disc type. Pin type insulators are installed in running line as shown in [Figure 1E](#) and discs are installed at dead pole in horizontal plane where jumper is used to further increase the length of line as shown in [Figure 1F](#). Single insulator disc is used for 11kV line between pole and conductor. Two discs can also be placed where osprey conductor is used as high mechanical strength is required. As the size of one disc is 6 inches hence there are many chances of electrocution because mostly birds use these poles for perching.

Faults on 11kV Line

The most frequent birds which cause tripping on 11kV feeder are Parya or black kite, doves, mynas and crows. These are most common birds found on 11kV feeders. The maximum size of Parya or black kite, dove, myna and crow is 66cm, 26cm, 23cm, and 40cm, respectively. The fatality of these birds is common on 11kV line due to dangerous design of poles. The rate of collision is low compared to electrocution because single line arrangement is used in the installation of 11kV line with Pin or horizontal Disc insulator. In our inspection we found many dead Parya or black kites and mynas which were burnt due to electrocution as shown in [Figure 2](#). The most common cause of tripping on 11kV line is also Clutch wire of vehicles which is fallen by birds on lines. A suspended wire on 11kV line is shown in [Figure 3A](#).

Phase to ground fault due to sitting of birds on insulator such as when they open their wings, there are

chances that their wings or body parts can strike with live conductor and pole which cause tripping as phase to ground fault.



Fig. 2. Bird (Myna) (A), bird of prey (Black Kite) (B) and bird of prey (Black Kite) (C).



Fig. 3. Suspended wire on 11kV Tata Pur Feeder (A), 1000MCM cable is used in 11kV line (B), Dangerous Pole (11kV) (C) and Dangerous Pole (400V) (D).

We have visited this line on different locations and found some places in 11kV line where 1000 MCM cable is used rather than bare conductor due to nearby houses, public transport, line crossing and for also the safety of birds as shown in [Figure 3B](#).

According to this survey, the bad construction of 11kV

line is the major cause of bird's death. It is very difficult to estimate the total number of birds lost by electrocution. We found many dangerous poles on a single inspection as shown in [Figure 3C](#) and [D](#). During inspection period, many dead birds were found under such dangerous poles. The bad design of the pole is the main cause of fatality because in some places a single pole is used for many purposes. A pole which is shown in [Figure 3C](#) supports two for 11kV lines and one for 400V line. The data consisted of burn marks on the feathers, feet, talons, flesh, or bills. These burns may be large and clear, or unnoticeable to the naked eye. Birds that are electrocuted may also show deformed or damaged talons that seem broken, curled, or incinerated and in some cases, the feet, toes, or talons are broken off ([APLIC, 2006](#)).

If a bird puts one leg on one line and another on the other line, then it will get roasted. During high temperature, the birds searching for shade may sit on lower cross arms or close to the pole. During rain or snow, they may use the lower parts of power poles. Birds become vulnerable to electrocution in rough weather, particularly rain, snow, and wind. The wet feathers of the bird increase conductivity and they face extreme difficulty in landing on power poles in high winds. A dry feather is almost as good an insulator

as air but a wet feather has evidently larger conductivity. A short circuit will occur when the nest in the line tower disperses and falls on wires.

Tripping data of 132kV grid station Vehari road Multan, Pakistan

Tripping data of 11kV Tata feeders for the year 2018 is shown in [Table III](#). The feeder which has most tripping is 11kV Feed Tata Pur. This feeder tripped eighty-six times in the month of July 2018. Tripping graph from January 2018 to December 2018 is shown in [Figure 4](#). The faults due to birds are temporary. After tripping on the feeder the grid team waits for five minutes and then again energizes the feeder. This method is used for three times. If the fault still remained then the team will inform the respective supervisor of that line and line will be taken into consideration in order to detect and clear the fault ([Fig. 5](#)).

Locations on google map

There are many 132kV high voltage grids and 11kV outgoing feeders in Multan, Pakistan. Their locations have been marked on Google map as shown in [Figure 6](#).

Table III. Monthly tripping data of 11kV Tata Pur feeder for the year of 2018.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
No. of feeder trippings	32	24	34	59	48	86	61	80	56	50	32	30

Table IV. Number of nests on power poles and affected birds.

Location (Taty-Pur)	Surrounding area	Common species	No. of nests (On power poles)	Affected birds (Jan to Dec 2018)
1 st part (20km)	Public transport, houses, communication lines etc.	Prey black kite	9	29
		Dove	-	6
		Myna	-	5
		Crow	5	17
		Pigeons	-	8
2 nd part (20-40km)	30% farms and 70% river	Prey black kite	7	48
		Dove	-	8
		Myna	-	9
		Crow	3	31
		Pigeons	-	11
3 rd part (40-60km)	75% farms and 35% river	Prey black kite	2	74
		Dove	-	13
		Myna	-	11
		Crow	2	57
		Pigeons	-	19

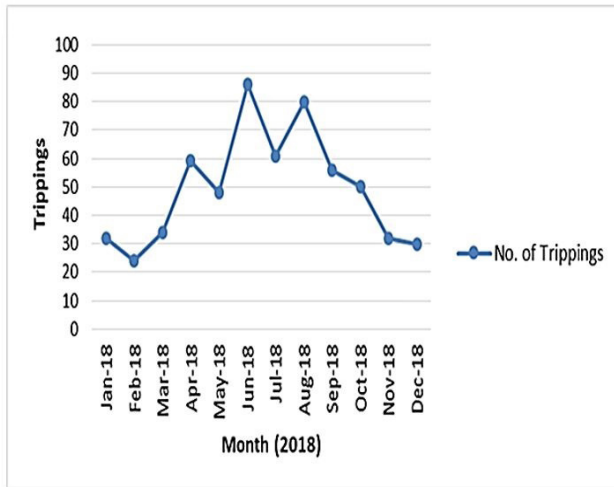


Fig. 4. Tripping graph of Tata Pur feeder.

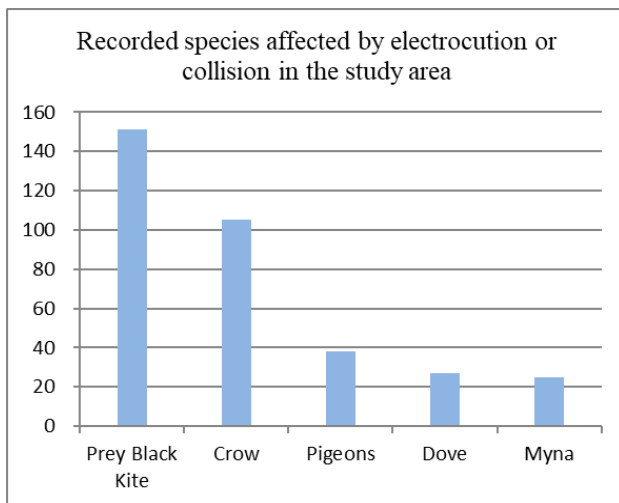


Fig. 5. Affected species in the study area.

DISCUSSION

During our survey under the supervision of Substation team, Department of Forestry, Range and Wildlife management, we observed Parya or black kite and crow are more exposed than other species. They were found in groups and in high numbers. We found many nests on power poles and depending on the location of these nests; they can be the cause of electric fire, electrocution and power outage as suggested by *Stehn and Wassenich (2008)*. These preys are using these poles for roosting, hunting and feeding purposes. Our team also measured most common species, number of nearby nests on power poles and number of affected birds. For the safety of birds, these issues must be raised at the level of electricity companies

and wild life management departments (*Shobrak, 2012*). These risks can be minimized by putting under-ground cables in water side or farm areas (*Bevanger and Broseth, 2004; Voronova et al., 2012*). If under-ground method is not applicable then there are many ways viz. a viz., installing proper bird boxes on towers, using ball reflectors etc. (*Janss and Ferrer, 1998*). In addition, we also need to aware the people that if they find injured or dead birds, what they should do? For this purpose, in our survey we also guided local residents and explained them the nature of wound/s. If they find a bird with a broken neck but still breathing then place it in a proper box, cover it and let it die humanely. In other case if the bird was bleeding and its condition was not alarming, then place some cloth on that wound for some time by applying firm pressure. If you still have some concerns, then call Wildlife Rehabilitators or Wildlife Organization.

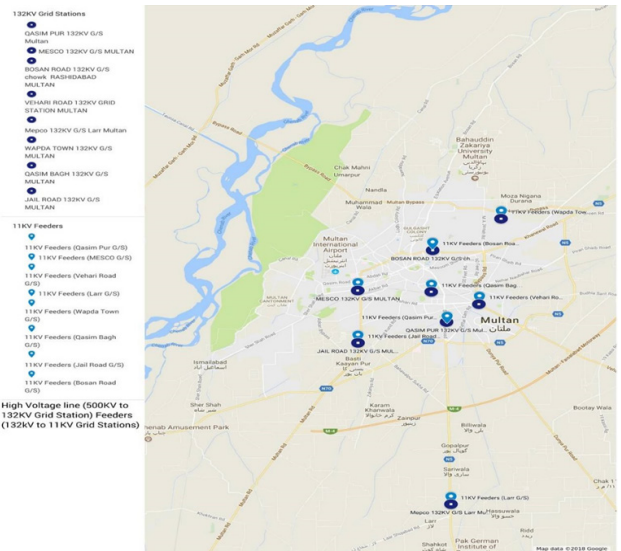


Fig. 6. Locations 132kV high voltage grids and 11kV outgoing feeders in Multan.

CONCLUSION

In this paper, various factors responsible for bird losses are presented that need to be solved. According to recent information, the risk of electrocution can be minimized significantly and cost-effectively. It can be accomplished by examining the necessary suggestions and the criteria for construction. As mentioned in the above section, the use of proper power pole construction is also safe for birds. Finally, birds are one of the precious creatures that keep the nature in balance. We need to protect them and minimize the hazards of technology on them. According to the results of this study; while the electricity transmission

and distribution system's continuity is increased due to fewer faults, it is ensured that safety is increased in the environment.

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Statement of conflict of interest

The authors have declared no conflict of interest.

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