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Protecting birds on powerlines:

a practical guide on the risks to birds from electricity transmission facilities and how to minimise any such adverse effects

Impressum

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1. Introduction

Around the world, the availability of electricity has become part of the standard of living. The transport of electricity from the power plants to the users is mainly via above-ground power lines. World-wide, this „wiring“ of the landscapes continues to increase and to advance even into the most remote parts of the inhabited continents. Most powerlines constructed so far pose fatal risks for birds and significantly affect the habitats of our large birds (in their breeding, staging and wintering areas). Today, the service life of above-ground powerlines must be assumed to be more than 50 years.

Above-ground powerlines pose three main risks or perils to birds:

- **risk of electrocution:** Birds sitting on power poles and / or conducting cables are killed if they cause short circuits (short circuit between phases, or short-to-ground). In particular, „bad engineering“ practised on medium-voltage power pole constructions has resulted in an enormous risk for numerous medium-sized and large birds, which use power poles as perching, roosting, and even nesting sites. Many species of large birds suffer heavy losses and are strongly decimated by electrocution. Some species are even threatened by extinction.
- **risk of collision:** In flight, birds can collide into the cables of powerlines, because the cables are difficult to perceive as obstacles. In most cases the impact of collision leads to immediate death or to fatal injuries and mutilations, which can not be survived.
- **risks and loss of habitat quality in staging and wintering areas:** mainly when above-ground powerlines cut across open landscapes and habitats (wetlands, steppe, etc.).

These topics are dealt within a large number of reports and publications from all continents. In Germany, the Working Group „Birds and Powerlines“ of NABU (Naturschutzbund e.V.) has been actively engaged for the last three decades. National and international studies were performed, relevant literature continuously monitored, a large archive of data and photographic records accumulated, and negotiations have taken place, which have led to satisfactory technical standards and legislation on national level.

In various parts of the world, different technical solutions for bird safety are under test and evaluation - so far still with moderate results. Unfortunately, many electric utility companies do not seem to be aware of the progress and of the current state-of-the-art, which has already been achieved for bird safety on powerlines. Sensible changes to the routing of the powerlines and changes to power pole / tower constructions can effectively reduce the risks posed to birds.

If at least all medium-voltage „killer poles“ were rendered safe, numerous endangered species of large birds, like storks, eagles and eagle owls, could recover and start to re-populate lost range. Attempts to re-introduce these birds will only be successful, if the main mortality factors, such as electrocution and collision, have been excluded to the best extent. It must be pointed out, that „killer poles“ pose a higher risk for a number of large birds, than all road traffic. The continued use of „killer poles“ is no longer acceptable and justifiable. These dangerous constructions must be expediently replaced or retrofitted for bird safety. It is regularly reported, that electrocuted and burning birds start large forest fires. In the USA „killer poles“ have led to final sentences with damage compensation payments by electric utility companies. Electric utility companies still ignoring the state-of-the-art and still using „killer poles“ must expect to be made liable for such damages.

According to current knowledge and experience, it is possible to reduce the risk of electrocution significantly, within acceptable cost for the electric utility companies. This can be achieved by observing the essential recommendations and construction criteria / principle for bird safety, as summarised in this brochure. This applies for new constructions and for retro-fitting kits. National government are recommended to pass suitable legislation, which makes the recommended technical standards for bird safety binding. The construction types of above-ground powerlines used in different countries have many similarities. Therefore the recommendations of this brochure have general, international validity. The catalogue of technical solutions for bird safety on medium-voltage power poles, as shown in this brochure, was already set up for an international initiative, that was accepted by the states of the Bonn Convention in September 2002 (55).

2. Bird species threatened by electrocution and / or collision

Bird casualties due to collision with above-ground powerlines can happen to any species of bird, capable of flight. Particularly at risk are birds migrating at night, birds flying in flocks, and / or large and heavy birds of limited manoeuvrability.

Casualties due to electrocution occur almost exclusively on badly designed medium-voltage power poles. Those species of birds that visit power poles, in order to perch, to roost and / or to nest are affected. In those regions and countries, where badly designed and constructed power poles are still in common use, some of our most impressive large birds, like storks, eagles, vultures, other raptors, ravens and owls, will suffer heavy losses. For some of these species, these continuing losses endanger their populations (see Fig.1).

In Table 1, the criticality of the losses due to electrocution and / or collision have been compiled for the different families of bird species. The following classifications are used:

0 - no casualties reported or likely

I - casualties reported, but no apparent threat for the respective bird population

II - regionally or locally large amount of casualties; however, these losses can still be compensated within the bird population

III - casualties are a major mortality factor; individual species are threatened towards extinction, regionally or on larger scale.

Table 1:
Criticality of bird losses due to (a) electrocution and / or (b) collision with powerlines for the different families of bird species

	(a) due to electrocution	(b) due to collisions
Loons (*Gaviidae*) and Grebes (*Podicipedidae*)	0	II
Shearwaters, Petrels (*Procellariidae*)	0	I - II
Bobbies, Gannets (*Sulidae*)	0	I - II
Pelicans (*Pelicanidae*)	I	II - III
Cormorants (*Phalacrocoracidae*)	I	II
Herons, Bitterns (*Ardeidae*)	I	II
Storks (*Ciconidae*)	III	III
Ibisses (*Threskiornithidae*)	I	II
Flamingos (*Phoenicopteridae*)	0	II
Ducks, Geese, Swans, Mergansers (*Anatidae*)	0	II
Raptors (*Accipitriformes* and *Falconiformes)*)	II - III	I - II
Partridges, Quails, Grouses (*Galliformes*)	0	II - III
Rails, Gallinules, Coots (*Rallidae*)	0	II - III
Cranes (*Gruidae*)	0	II - III
Bustards (*Otidae*)	0	III
Shorebirds / Waders (*Charadriidae + Scolopacidae*)	I	II - III
Skuas (*Sterkorariidae*) and Gulls (*Laridae*)	I	II
Terns (*Sternidae*)	0 - I	II
Auks (*Alcidae*)	0	I
Sandgrouses (*Pteroclididae*)	0	II
Pigeons, Doves (*Columbidae*)	II	II
Cuckoos (*Cuculidae*)	0	II
Owls (*Strigiformes*)	I - II	II - III
Nightjars (*Caprimulgidae*) and Swifts (*Apodidae*)	0	II
Hoopoes (*Upudidae*) and Kingfishers (*Alcedinidae*)	I	II
Bee-eaters (*Meropidae*)	0 - I	II
Rollers (*Coraciidae*) and Parrots (*Psittadidae*)	I	II
Woodpeckers (*Picidae*)	I	II
Ravens, Crows, Jays (*Corvidae*)	II - III	I - II
Medium-sized and small songbirds (*Passeriformes*)	I	II

3. Typical injuries and economic damages caused by bird accidents

In most cases, accidents on over-ground powerlines lead to severe injuries or immediate death. **Electrocution** harms mostly birds sitting on the ground rail or having ground contact. Current passage through the body causes primary damages to tissues and impaired functions: muscles and nerves abruptly stop functioning. The bird will fall from the pole and crash onto the ground, where the bird suffers further serious injuries.

In case of **collision** accidents, birds crash at high flight speed into cables or wires. The resulting injuries vary widely and are comparable to traumata caused by collisions with cars (109,110).

Typical injuries (a) from electrocution and (b) from collisions are summarised in Table 2, and are illustrated by Fig. 2 – 7 and 28. In rare cases, collision and electrocution occur at the same time, when two closely spaced conductors are shorted by the bird (see Fig. 6).

Table 2:
Typical primary injuries and secondary damages to birds caused by electrocution, respectively by collision. (Note: Only a small number survives the severe accidents for some time.)

	(a) Electrocution	(b) Collision
Predominant bone fractures	fractured vertebrae with paraplegia; skull fractures, fractured pelvic bones	fractured bones of the extremities: wings, legs and shoulder bones, vertebra and skull fractures; torn off limbs
Damages to plumage	burn marks: small, well-defined burn holes in the plumage; in case of arcing: large parts of plumage are burnt	mechanical damages, like torn-out or broken-off feathers; in rare cases: burnt plumage from short-circuit
Skin injuries	Burn marks: mainly very small scorched areas at current entry and exit points. If bird survives untreated, large areas of dead skin and necrotic extremities develop	torn open and torn off skin, open muscle, sinew and bone tissue; without immediate treatment, infections and necrosis will develop
Secondary damages on extremities	large necrotic areas on the limbs affected by current flow (largely of completely necrotic)	limited areas of necrosis at the open wounds, bones, sinews, muscles; bacterial infections
General condition of injured birds	Initially: state of shock; then irreversible damages by limbs dying-off	state of shock; handicapped by injuries and secondary damages

The technical installations of the powerline can also take damage from bird accidents: collisions can cause conductor cables to sever or to strike together. Short-circuits to ground can damage insulators and switches. Bird accidents can lead to outages and economic damages.

- Birds which are set afire by electrocution or arcing, can set off forest fires. This is a frequent cause in hot climates like in the Mediterranean, but also in moderate and artic climates during dry summers.
- Bird accidents on the medium-voltage network of railroads can lead to traffic interruptions, associated economic damage, and inconveniences for the passengers.
- On high-voltage powerlines too, short-circuits can cause outages: Short-circuits are caused by a jet of urine from large birds roosting on the cross arm above the suspended insulators.
- Nests on top of power poles: Repeated urination and droppings can impair the function of the insulators, without injuring the nesting birds.

To a large extent, bird safety is also in the economic interest of the utility companies and enterprises. Measures for bird safety (collision) are also of benefit for flight safety: collision risks for parachutists, ultra-light and light planes or rescue helicopter will also be reduced.

4. Extent of risk and casualties

4.1. Bird losses due to electrocution

Birds are attracted by power poles, just like they are attracted by large dead trees in the open country-side. They are favoured as lookout points, as well as perching and roosting sites, and sometimes as nesting sites.
Some commonly used constructions of medium-voltage power poles became infamously known as „killer poles“ which cause high bird losses. In those regions and countries, where such „killer poles“ are commonly used on medium-voltage power lines, numerous species of large birds suffer severe losses. Field research and investigations on storks, vultures, eagles and eagle owls have shown, that already these losses alone can drive these bird species into decline and towards extinction.
There is no hope that large birds will eventually adapt themselves to some of the very dangerous types of medium-voltage power poles. There is no alternative, but to make all medium-voltage power poles safe for birds by:

- changing to constructions, that are safe for birds according to recognised technical standards (see chapter 7.2.1)
- retrofitting the existing „killer poles“ in accordance with recognised technical standards (see chapter 7.2.1).

It is the combination of badly engineered insulator and conductor constructions and of the attractiveness of power poles for many birds that explains the high risk posed to birds. In particular, if the spacing of the energised wires (phases) is particularly small, if only very short insulators are used, or if protective gaps (arcing horns for lightning protection) are installed on a power pole, birds down to the size of Starlings (*Sturnus vulgaris*) or even down to the size of House Sparrows (*Passer domesticus*) will often become electrocuted (Fig. 4 and22). It is pointed out that even songbirds can burst into flames, when electrocuted, and can ignite wild fires and / or forest fires (see Fig. 4).
It is very difficult to estimate the total number of large birds lost by electrocution. Monitoring is difficult, because large birds have a large range where they can die and large dead birds are quickly taken away by raptors, foxes, badgers. It was not until banding programs and the analysis of ring recoveries, respectively the monitoring of birds fitted with radio transmitters, revealed the disastrous toll due to electrocution.

At certain locations, remarkable numbers of dead birds were found below „killer poles“. Under a single power pole at a garbage dump in Southern Germany, the remains of 28 birds

were found on a single inspection, including 4 Eagle Owls (*Bubo bubo*) and 3 Kites (*Milvus milvus* and *Milvus migrans*).
In a staging area in Kasakstan, a total of some hundred bird casualties were reported from a 11 km of powerline in October 2000. The casualties included 200 Kestrels (*Falco tinnunculus*), 48 Steppe Eagles (*Aquila nipalensis*), 2 Imperial Eagles (*Aquila heliaca*), 1 White-Tailed Eagle (*Haliaeetus albicilla*) and one Black Vulture (*Aegypius monachus*).

4.2. Bird losses due to collisions with powerlines

In principle, birds of any flying species can become victims of collisions with some type of aerial wires or cables: This concerns telephone / telegraph lines, as well as low-voltage, medium-voltage and high-voltage powerlines. High losses are reported from lines with thin and low-hanging wires in sensitive areas: rails, waders / shorebirds and sand grouses.

Fortunately, many types of electric lines will be removed with the continuing technical progress. In many countries, overhead telephone and telegraph lines will continue to disappear. In addition favourable trends can be reported from the low-voltage and medium-voltage networks of some utility companies, which have made the step to change from above-ground powerlines to under-ground powerlines. Two examples are given:

- In Holland, all low-voltage and medium-voltage supply lines of the utility companies are under-ground. Bird losses due to electrocution and / or collision are altogether avoided (exceptions: medium-voltage network of the railways, and the high-voltage network). These favourable conditions explain in part the remarkable results by bird protection in Holland.
- In Northern Germany, the utility company Schleswag AG stopped building above-ground medium-voltage powerlines in 1989, and started to successively replaces existing above-ground powerlines by under-ground powerlines. Eventually, all above-ground medium-voltage powerlines will disappear, and loss due to electrocution and / or collisions will no longer occur.

In many parts of Germany, more than 50% of the medium-voltage network are already under-ground. In addition the low-voltage overhead powerlines continue to be replaced and to disappear.

Under-ground cables for high-voltage and highest voltage energy transport are expensive technical solutions and are only used in exceptional cases. Therefore, all over the world above-ground powerlines will remain in use for high-voltage and highest-voltage power transmission (60,000 to 750,000 Volt). At these high voltages, safety standards require high-hanging cables. The towers of these powerlines often rise to heights of 50 m. Migrating birds flying at heights between 20 m and 50m are at considerable risk of collision.

Many important investigations on bird collision were performed on high- and highest-voltage powerlines. From randomly selected sections of powerlines in the interior often quite low collision losses are reported. However, in important areas of bird migration considerable losses occur. Birds migrating at night and birds flying regularly between feeding areas and resting areas are particularly at risk, when powerlines cut across their migration corridors or their staging / wintering areas. At such locations, bird losses can exceed 500 casualties per kilometre of powerline. Especially long-distance migratory birds have to cross a large number of powerlines during their autumn and spring migrations - at considerable risk (124,194 etc).

Especially in the case of rare species, collision losses represent an additional, substantial mortality factor. In order to reduce collision losses, bird protection must be taken into account early in the planning stage of any new above-ground powerline. Prior to or in the initial stages of planning, one year of field work is necessary for ornithological evaluation and for the investigation of local flight routes and patterns during migration, breeding and post-breeding seasons. The resulting findings and recommendations must be reflected in the routing and in the construction features of the power line (see also chapter 7.2.2).

Breeding birds, which are mostly resident birds, can adapt to obstacles in their habitat. Not so birds on migration and during stopovers, because they remain in the area only for a limited time. Dangerous and wrong flight manoeuvres, which can lead to collisions with cables and wires, are observed more often from migratory birds, than from resident birds.

High risk potential can be stated for:

- areas of high avifaunistic importance and of high importance during migration
- areas with high bird populations and high percentage of migratory birds
- wetlands, marshes, coastal areas, steppes
- migratory birds, when powerlines cross their flight path at right-angle
- birds migrating at night are at highest risk.

Influences and conditions, which increase the risk of collision:

- any disturbances leading to panic flight movements (which is often caused by hunting)
- bad visibility of the conductor cables, which are coated with aluminium oxide (grey coloured)
- unfavourable weather conditions, like fog, precipitation, strong head winds. Under these conditions, bird migration concentrated at lower height - at the height of the overhead cables.
- most collision accidents happen during the night and during dawn and dusk.

Particularly high losses are reported where powerlines cut across important flyways and migration corridors, such as river valleys, valleys between mountains, straits, etc. Above-ground powerlines in staging and wintering areas also cause a high toll of collision casualties: in wetlands, in steppe areas, in particular when they separate resting areas and feeding areas. Power lines in the flight approach of important staging and feeding areas, in particular close to water, are critical.

An extrapolation of the bird losses for Holland (172) provides a good indication of the average collision risk from high-voltage above-ground powerlines. The Dutch high-voltage supply network comprises 4,200 km of powerlines. Estimated are 500,000 to 1,000,000 collision casualties per year. Until 1997, improvements for bird protection were introduced on 13 percent of the high-voltage supply network: cables and in particular the zero wire were marked for better visibility. The improvements were made on powerlines, where high losses had been reported. It is estimated that the casualties were reduced by 185,000 birds per year.

5. Degradation of habitat quality in staging and wintering areas

5.1. Electrocution

In those regions and countries, where „killer poles“ are commonly used on medium-voltage power lines, a full spectrum of large birds are at risk. Very short upright insulators on these power poles are dangerous for birds down below the size of doves. „Killer poles“ -

commonly used in Hungary and in Russia - are a high mortality factor for all birds of prey, with the exception of harriers, which seldom perch or roost on power poles.

On their migration routes, numerous species of large birds are significantly decimated by electrocution. An important example are the White Storks (*Ciconia ciconia*). White Stork banding programs have shown that electrocution along the European migration routes of the White Stork represents the main cause of death. „Killer poles“ in prime habitats for large birds logically lead to the highest losses of large birds. In these habitats, measures for bird protection have the greatest effect.

Also man-made (secondary) habitats can be of great attraction for large birds. White Storks for example spend winter in increasing numbers on large garbage dumps like those in southern Spain. At such secondary wintering habitats, too it is highly effective to make „killer poles“ safe for birds.

5.2. Collisions with above-ground powerlines

As already outlined in chapter 4.2.2, above-ground powerlines degrade the quality of staging and wintering habitats. This includes above-ground powerlines in the flight approach and powerlines between foraging / feeding areas and roosting areas during migration and wintering.

5.3. Habitat Changes

Above-ground powerlines increase the mortality rate of birds of the open habitats, like steppe, meadowlands, marshes, etc. by collision and by increased predation (from the lines attracted mammalian predators and by providing perching sites and lookouts for birds of prey). Arctic geese avoid the close vicinity of powerlines, when feeding. Above-ground powerlines can lead to the loss of useable feeding areas in staging and wintering habitats (Fig. 11; 176) .

On the other hand, power poles offer perching, roosting and nesting sites for some large birds. Bird-safe powerlines enable birds, like raptors, storks, ravens, to nest in otherwise treeless landscapes.

Powerlines influence habitat structures and have a significant impact on the vertebrate fauna of an area. During the planning phase of each new powerline, the pros and cons and the priorities in conservation must be carefully weighed and traded.

6. Different construction types of electric transmission lines and their risks to birds

6.1. Low-voltage powerlines

In a number of countries, all or most of the low-voltage supply lines are routed underground, which is the best solution for bird safety. Often, low-voltage supply lines use well-insulated cables, directly attached to support poles (see Fig.12), which is the second-best solution. Collision risk are minimised, because the well-visible black cables replace a number of conductor wires.

On low-voltage overhead powerlines, the risk of electrocution is low, because of the relatively low voltage and the high electric resistance of birds (see Fig. 13). However, climbing and flying mammals can be electrocuted and can cause damage to the powerlines. In tropical countries, large bats (flying foxes) are often seen electrocuted on low-voltage powerlines (multi-level arrangement of wires, and closely spaced wires) - see Fig. 14.

The collision risk on low-voltage powerlines is higher, when thin wires are used, which are hardly visible against the background. Generally, the collision risk can be reduced by using single-level wire arrangements, or by changing to insulated cables – if earth cables are not used (see Fig. 12).

6.2. Medium-voltage powerlines

6.2.1. Powerlines of utility companies

In some countries and by some electric utility companies, the whole medium-voltage power network has been laid under-ground. However, world-wide the majority are still above-ground powerlines. Medium-voltage range: 1,000 Volt to 59,000 Volt.

Often, the conductor cables are attached via relatively short insulators to poles constructed of conducting material. Birds on the grounded pole can easily reach the energised conductor cables, or vice-versa. The body of the bird causes a short circuit to ground (see Fig. 15, 35 etc.). As illustrated in Table 1, such „killer poles“ are a large danger to many species of large birds, all over the globe.

On the other hand, power pole constructions exist, which are almost perfectly safe for birds. In some countries, such bird-safe constructions were made mandatory by regulations and technical standards. Fig. 10, 15, 23, 27, 29 and 30 - 35 illustrate widely used „killer poles“, and Fig. 25 a and b, 26, 29, 31, 32 and 33 show power pole constructions, which are safe for birds.

Closely spaced conductors, less than 1.40 m apart, are often the cause for fatal short-circuits, when birds touch both conductors simultaneously (see Fig. 53). Such short distances between conductors of different phase are often seen on Switch Towers (see Fig. 20).

The risk of collision also exists with medium-voltage powerlines. Fortunately, most medium-voltage powerlines have conductor cables arranged on one level, which reduces the risk. Neutral conductors on a level above the energised conductors are occasionally seen (see Fig. 30). They should be removed for bird safety reasons.

6.2.2. Powerlines of the railways

Overhead powerlines of the railways transmit power at typically 10,000 Volt to 15,000 Volt. This corresponds to the medium-voltage range of the electric utility companies, and similar aspects of bird safety must be taken into consideration. Also the railroads use different construction types: beside bird-safe solutions (see Fig.31), also „killer poles“ are in use. These different types can be found next to each other(Fig. 32,33 and 34). In the past, these dangerous powerlines received little attention. This is surprising, because electrocution accidents with birds and mammals have led to interruptions of railroad traffic.

6.3. High-voltage powerlines

High-voltage powerlines are almost exclusively above ground. Because of their long suspended insulators, the risk of electrocution is low (see Fig. 39). Nevertheless, fatalities by electrocution are reported: in humid weather, troops of small birds can cause arcing; arcing can also be caused by the urination jet of large birds roosting on the crossarm above the insulators. The latter can be avoided by suitably arranged bird rejectors above the insulators
(Fig. 37, 42).
Death by collision with the cables is by far the largest peril posed by high-voltage powerlines. Different tower constructions are in use and have different levels of risk. Tower constructions are not only driven by technical necessities, but also by national standards and regulations and in particular by design heritage and traditions of the different electric utility companies.
Highest risk are posed by those powerlines, where the conductor cables are arranged at different heights (multi-level arrangements) and with neutral cables high above the conductor cables (Fig. 37, 44, 45, 46). On the other side, less dangerous constructions are in use, which have the conductor cables arranged at one height (single-level arrangement) and with the neutral cable only slightly higher (see Fig. 38, 39). These construction fulfil the same purpose as the high multi-level towers, but pose a significantly reduced risk. Even more favourable are those single-level powerlines, which use no neutral cable at all (see Fig. 40, 41).

In special risk zones for air traffic, e.g. under the entry lanes of airports or airfields, or when motorways are crossed, special constructions are installed for air safety (jet planes, police and rescue helicopters) on powerlines using otherwise constructions of high collision risk:

- single-level arrangement: multi-level tower are replaced by double poles
- markings for daylight using well-visible balls on the neutral cables
- warning lamps at night.

Such technical measures reduce also the risk of collision for birds, as well as for gliders, or for light airplanes in emergency situations with poor visibility conditions due to weather changes. Some progressive utility companies use such low-risk constructions already on a larger scale .

If on newly erected power lines the neutral cable high above the conductor cables is not left away, or for bird safety on existing powerlines, the thin neutral cable should be made clearly visible by suitable markers. Such provisions allow to reduce collision accidents by 50 to 85 percent, because most collision accidents occur at the thin neutral cable: At close range, birds recognise the relatively thick conductor cables and perform obstacle avoidance manoeuvres, that can lead them crashing into the thin neutral cable.

As markers for better visibility of the neutral cable, vertically hanging black and white plastic flaps proved most effective. Often, plastic spirals are used (Abb. 44 - 49), which can be dangerous in another way (Fig. 46). According to recent investigations, black and white oval structures, which flash and rotate in the wind have a high warning effect, but are not yet used. Nevertheless, all of these warning provisions are less effective than the removal of the neutral cable high above the conductor cables.

6.4. Other wire constructions

Similar to the cables and wires of above-ground powerlines, other cable constructions pose collision risks to birds. These are funiculars, suspension and tension cables of bridges and of broadcasting masts.

Also wires and wire constructions low above ground cause collision fatalities of many species of bird: barbed wire fences on pastures, fences around forest nurseries, and even clothes lines (Fig. 50, 51, 52). Hunting raptors and owls, snipes during aerial display, etc. often collide with barbed wires on pastures. The extent of such collision losses is much smaller than the losses from electrocution or collision on powerlines. The losses of White Storks by barbed wire are less than 5 percent of the losses on powerlines.

7. Recommendations

7.1. Experience from conservationists' work

Voluntary agreements between electric utility companies and conservationists are rare. Where good co-operation has been achieved, the results are of local or very regional nature, e.g. the replacement of some extremely dangerous „killer poles". Overall, the effect of such effort is negligible, in particular when „killer poles" remain in use or are newly constructed at other locations.
The responsibility of the electric utility companies to observe bird safety is in the public interest and is also a matter of ethics. Satisfactory results can only be expected upon clear legislative action.
Utility companies prefer low-cost constructions, where possible, and often counter conservationists' arguments with pseudo-economic reasoning.
In some countries, like Hungary, the situation is almost absurd: „Killer poles" are the only government approved technical standard and must be used.
Highly dangerous constructions are still frequent in high voltage powerlines, which obstruct the air space and thus the bird migration routes by multiple levels of cables.
In order to enforce the state-of-the-art of bird safety, clear and unambiguous legislative action is imperative. In several countries, the „killer poles" started to disappear or to be retro-fitted on a large scale only after legislative action. In Germany, the construction of new „killer poles" became generally prohibited, and all existing power poles must be made safe by 2011. A catalogue of suitable designs and solutions was set up by the electric utility companies, in close co-operation with government and conservation groups.

7.2. Technical Standards

7.2.1 Standards to protect birds from electrocution

Technical standards are recognised and binding design guidelines for the construction of powerlines. These standards should contain a Bird Protection Clause, with the general requirement that the objectives of bird protection must be respected, and which prohibits the use of any type of „killer poles". The introduction of a Bird Protection Clause was an important requisite to ultimately remove „killer poles" in Germany. The wording of the Bird Protection Clause is the following:

„Crossarms, insulators and other parts of high voltage powerlines shall be constructed so that birds find no opportunity to perch near energized power lines that might be hazardous." (VDE 0210, 1985, section 8.10 Bird Protection)

In the new German Federal Nature Conservation Law passed in 2002, the necessary steps toward bird-safety on power poles were clearly defined. Bird protection must reflect the state-of-the-art and must follow the detailed design guidelines and criteria described in the catalogue „Vogelschutz an Freileitungen“, VDEW-Verlag, 2nd edition, 1991.
The new Paragraph 53 “Bird Protection on power lines dictates:
“Newly erected power poles and technical hardware have to be constructed to exclude the possibility of bird electrocution. Mitigating measures are to be undertaken on existing power poles and technical hardware in the medium voltage range within the next ten years.(...)”
The technical measures already taken in accordance with this new technical standard had already significant effects: the populations of endangered species of large birds, such as White Stork, Black Stork, White-tailed Eagle, Osprey, Red Kite and Eagle Owls have started to recover or have at least stabilised.

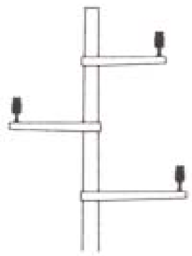
In Germany, a large amount of long-term experience is available, because different methods for bird-safety on powerlines were tested - and many of them were found to be ineffective. This experience can be seen as international benefit, because the construction principles of medium-voltage powerlines are the same world-wide. Therefore the design guidelines and technical standards for bird safety elaborated in Germany can be reused world-wide. Some essentials are discussed and illustrated on the following sides:

The following describes the most widely used types of power poles worldwide, their potential risk and steps towards mitigation. Recommendations are made for power poles made of concrete, steel, composite steel and wood. This brochure is based on standards set up by the Vereinigung Deutscher Elektrizitätswerke (1991) as well as studies carried out by the NABU National Working Group on Electrocution (2002).
The safety of the installations depends primarily on

- Ø how insulators are attached to the poles and
- Ø the actual space between the power cables and other energized and grounded parts.

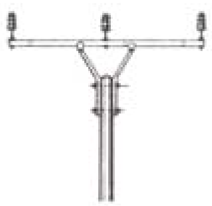
POWER POLES WITH UPRIGHT INSULATORS

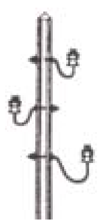
Power poles with upright insulators are widely used and rank as the most dangerous of all types. The gap between the cables and the crossarm is small, in older structures the lines run along the side of the top of the power pole.



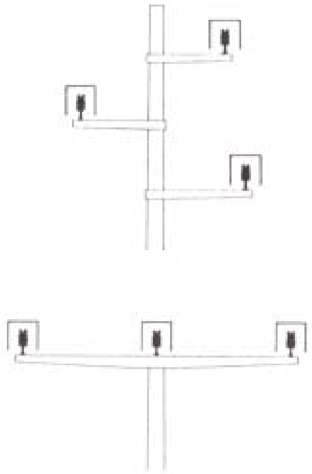
risk: high

In wet weather **wooden poles** with upright insulators can be a hazard as well as poles that are grounded. The top of armless poles has to be well above the uppermost wire.



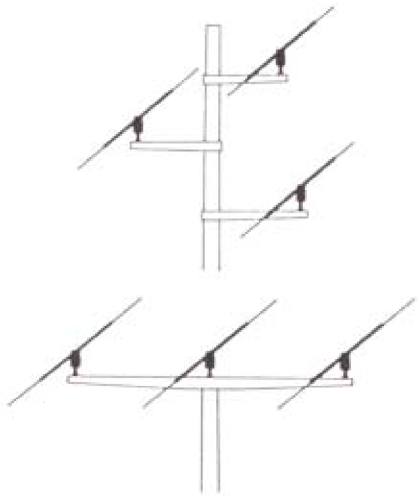


Mitigating electrocution effectively is possible either by treating poles (a) with insulating caps made of plastic for outdoor use 130 cm in length or (b) insulating power lines with tubing 130 cm in length. The conductors have to be spaced at a distance of at least 140 cm. If this is not possible, they should be insulated with tubing.

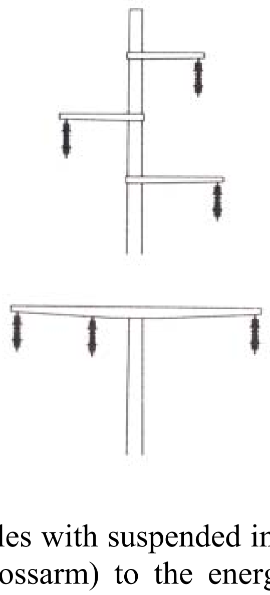


Suggested Practices:

(a) Insulated caps (above)
(b) Tubing (below)



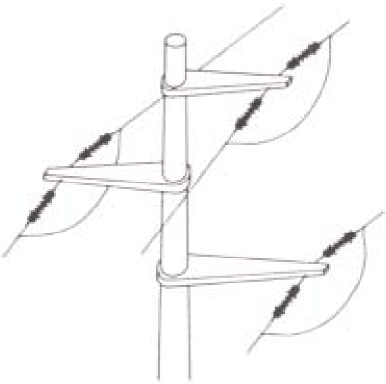
POWER POLES WITH SUSPENDED INSULATORS

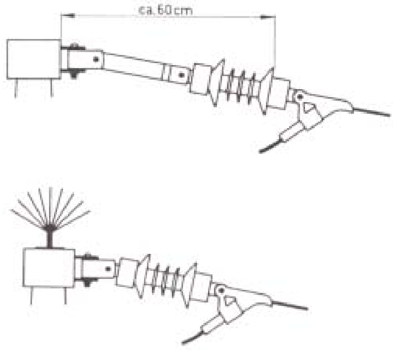


Poles with suspended insulators are fairly safe provided the distance between a likely perch (crossarm) to the energized parts (conductors) is at least 60 cm. Conductors should be spaced at least 140 cm apart. Hardware that is used to prevent arcing ("St. Elmo´s fire" on both sides of the insulators) should not be used.

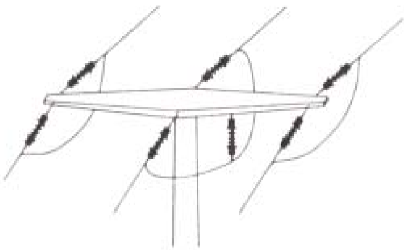
STRAIN POLES

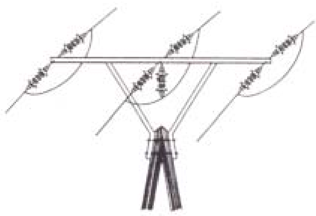
Strain poles with power lines below the crossarm: risk low





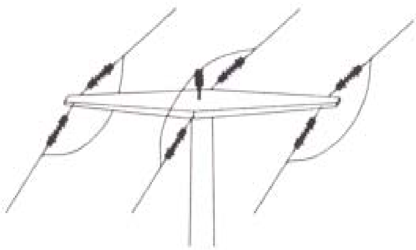
Suggested practices:
Lengthening of the chain (above)
Perch rejectors, made of plastic rods (below)

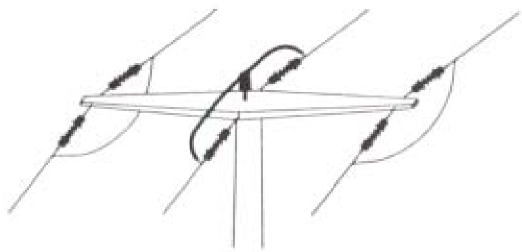


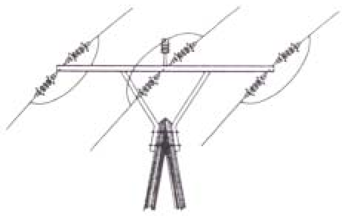


Bird-safe strain poles require insulating chains at least 60 cm in length. Hazardous constructions can be mitigated by (a) lengthening the chains or (b) installing perch rejectors (upright "whisk brooms") on the crossarms. In instance where the conductors run above or too close to the crossarm, (c) tubing should be used. Junction power poles should be treated in the same way.

Strain poles with one conductor above the crossarm. Risk: high

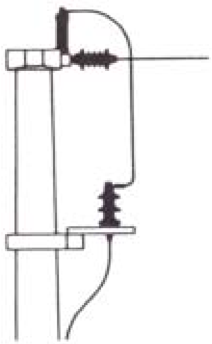




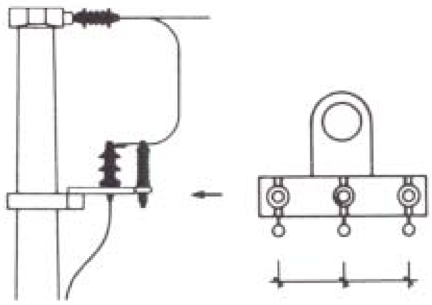


Suggested practices:
Insulated hood or insulated tubing

TERMINAL POLES AND TOWER STATIONS

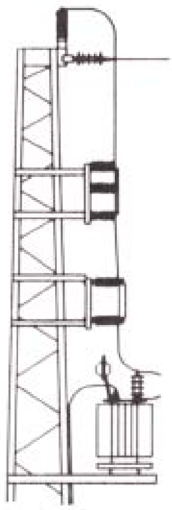


Terminal pole Risk: high

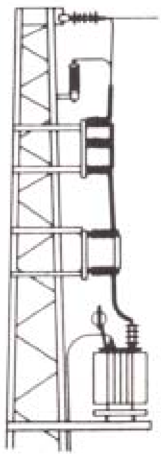


Terminal pole. Suggested practices (see legend)

Frequently over voltage reactors extend above the tops of terminal poles and tower stations. This hazard for birds can be avoided if the over voltage reactor is attached below the crossarm and all exposed wire contacts are insulated with tubing. On tower stations all contacts directly above the switch as well as between the switch and transformer should be treated likely. Hardware used to prevent electrical arcs should not be used (mitigation measure : dismantle).



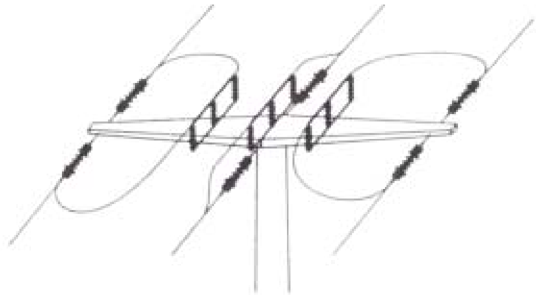
Tower station Risk: high



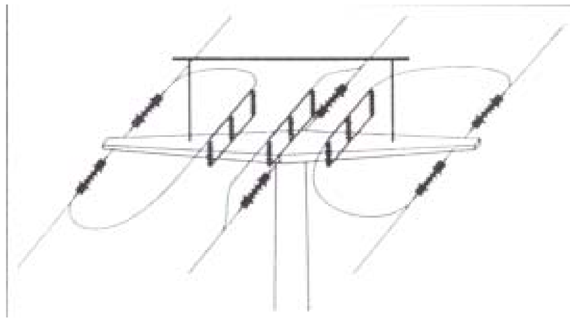
Suggested practices see legend

SWITCH TOWERS

The safest switch towers have their switches attached below the crossarm. Otherwise, mitigation measures are more complicated and do not provide the same high degree of safety for birds. As hooding is usually not possible, various techniques have been tested.

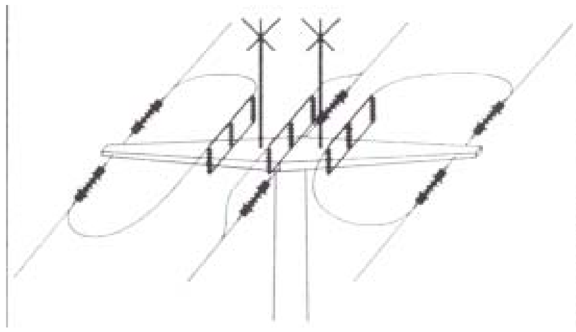


Switch tower **Risk: high**

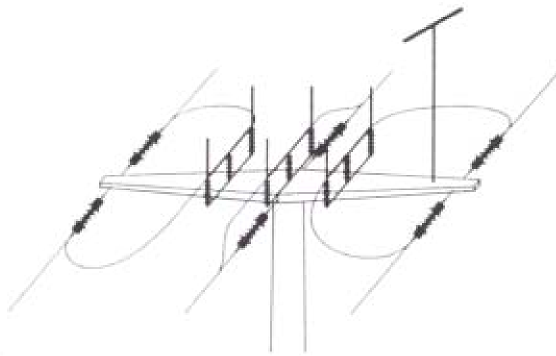


Suggested practices
(a) Insulated perch sites

Insulated perch sites can be installed (a) lengthwise to the crossarm or (c) at its edge. They should be as long as possible and have a rough texture. Perching deterrents (“St. Andrew`s Cross”) (b) installed above the switch keep birds from perching on the poles, as does the installation of acrylic glass rods (c).



(b) St. Andrew`s Cross



(a) Insulated perch sites lengthwise to the crossarm and acrylic glass rods

In the case of medium-voltage powerlines of the railways, similar modifications or new constructions must become mandatory: they reduce bird losses and improve railway safety. In Germany, railway engineers, conservationists and government representatives are in the process of elaborating detailed technical standards and design guidelines, which take into consideration bird safety. Fig. 31 to Fig. 33 illustrate, that bird safety can be introduced without large technical effort.

7.2.2 Standards to protect birds from collisions

For the safety of air traffic and for the minimisation of fatal bird collision on powerlines, the following requirements must be applied to all powerlines:

- Constructions shall obstruct only a minimum of air space in vertical direction: Single-level arrangement of conductor cables; no neutral cable above the conductor cables.
- Infrastructures shall be bundled, where possible, e.g. powerlines to be routed along roads and railways, in order to maintain open unfragmented landscapes.
- Under-ground cables are recommended, where possible.
- „Hiding“ of the powerlines: above-ground powerlines should be routed as low as permissible, behind buildings or rows of trees, at the foot of hills or mountains.
- Attachment of well-visible black-and-white markers on cables posing a high collision risk, in particular the neutral cable of high-voltage powerlines
- Careful preparatory investigations of different routing alternatives: bird migration often follows local or regional flyways determined by topology, shorelines, etc. Prior to the planning of any new powerlines, such investigations are needed and must comprise bird migration at day and night time and other seasonal phenomena.
- On new powerlines, those design solutions should be selected, which need no markers or protective covers. The durability of these elements is not compatible with the average service life of powerlines of 50 years.

Already during the planning phase of new powerlines, detailed ornithological information is needed. Good co-operation and dialogue between electric utility companies and conservationists are essential to arrive at optimal solutions - which is in public interest.

7.3. Recommendations for national and international legislation

In Germany, the erection of „killer poles“ was for quite some time in conflict with laws, such as the Nature Conservation Law, the Animal Conservation Law and the Hunting Law. (legal expert opinion of Dr. Dr. K. Sojka, 1975). Only the new and detailed regulations brought about the necessary changes. World-wide the first state to implement these regulations was the German state of Baden-Württemberg, where was passed in parliament in 1991 respective legislation (see also legend of Fig.1).

In al countries where good cooperation exists between energy utility companies and conservationists, but detailed technical standards and respective legislation has not been passed, the problem of the „killer poles“ could not be resolved satisfactorily. For example, typical „kill poles“ are still erected in some states of the USA.

Because world-wide the problem of „killer poles“ is still on the increase, with disastrous effects on many populations of endangered species of large birds, all countries are urgently recommended to pass effective legislation. The effectiveness of the steps taken in Germany and other central European countries is undisputable and can serve as reference.

It is recommended to the Environmental Organisation of the UN, That guidelines should be issued, comparable to those of the WHO on medical matters. These guidelines should include the recommendations made with respect to collision avoidance on powerlines.

7.4. Further research

A significant handicap in the negotiations with electric utility companies is the fact that scientific investigations on bird protections and related ornithological investigations are hardly known and cannot be found in the electroengineering professional periodicals.

On regional and local level, a large need exists for ornithological investigations prior or during the planning phase of new powerlines. One year of ornithological investigations are needed in order to characterise local and regional bird migration pattern and other bird movements, as input to the routing and construction of the powerline.

The durability of many bird-protection armatures must be significantly improved. The used materials must withstand all weather conditions and UV light for decades. Markers on high-voltage cables must be compatible with high electric fields and high heat input. In practical application, worn out protective caps or markers are a nuisance. Until materials of acceptable long-term stability and durability for use on insulators and cables are available, construction measures must remain the preferred solution for new powerlines.

Further investigations are needed, in order to find solutions which can do without the neutral cable high above the conductor cables. Exchange of information is recommended with those electric utility companies, that removed the neutral cables on their high-voltage powerlines.

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!0. Legend to the Figures

Fig 1: Typical spectrum of electrocuted birds from Baden-Württemberg – a region in Southern Germany: White Storks (*Ciconia ciconia*), Black Stork *(Ciconia nigra)*, Grey Heron *(Ardea cinerea),* Red Kite *(Milvus milvus)* , Peregrine Falcon (*Falco peregrinus*), Eagle Owl *(Bubo bubo*), Barn Owl (*Tyto alba*), Kestrels (*Falco tinnunculus*) – Carrion Crows (*Corvus corone corone*) and Buzzards (*Buteo buteo*) were not displayed. The picture was taken in 1988 at the Bird Rehabilitation Centre of D.Haas. It is a historical record, because in 1991 the government of Baden-Württemberg introduced a law, that required all dangerous "killer-poles" to be made safe for birds within 10 years. Mainly large birds have benefited: White Storks are again increasing and spreading, Black Storks have returned to breed in Baden-Württemberg after they had gone for almost 100 years. Also the Eagle Owls could increase their range , and occupy now suitable habitats in the whole Baden-Württemberg. Germany Photo: D.Haas

Fig. 2: Crippling secondary damages after Kestrels *(Falco tinnunculus*) had survived electrocution: limbs (talons and parts of the wings) died off. Germany Photo: D.Haas

Fig. 3: White Stork (*Ciconia ciconia*), adult male, almost completed burnt by electrocution. Germany Photo: D.Haas

Fig. 4: Starling (*Sturnus vulgaris*), electrocuted and burnt up on a „killerpole" with very short upright insulators. Hungary. Photo: U.Mades

Fig. 5: Also this can happen: a Kestrel (*Falco tinnunculus*) survived electrocution with largely scorched plumage, and was rehabilitated and released after moult. Germany. Photo: D.Haas

Fig. 6: A Crane (*Grus grus*) collided during migration at night with a medium-voltage powerline: one conductor cable was severed, and the bird also caused a short-circuit between the closely spaced conductor cables. The bird was burnt up to a large extent. Germany. Photo: D.Haas

Fig. 7: Woodcock (*Scolopax rusticola*), collision casualty on a medium-voltage powerline exhibiting typical fatal injuries from collision: skull trauma, skin shaved from the head, abdomen ripped open. Germany Photo: D.Haas

Fig. 8: Purple Heron (*Ardea purpurea*), collision casualty. The bird attempted, as herons do, to fend off the impact with its beak and became entangled and died. Croatia Photo: K.Anka

Fig. 9: Great Bustard (Otis tarda), adult female with mature egg in the abdomen, collision casualty of a high-voltage power line. Note: All conducting cables are at the same height, which is favourable; much more dangerous are the two neutral cables, high above the conducting cables. Spain Photo: D.Haas

Fig. 10: This insulator damage was observed, after five crows had been electrocuted at this site. Germany Photo: D.Haas

Fig. 11: Arctic geese (Brent Goose – Brenta bernicla and Pink-footed Goose – Anser brachyrhynchus) in their wintering area. The immediate vicinity of the medium-voltage powerline is avoided. Important feeding areas and resources are lost. Denmark Photo: G.Fiedler

Fig. 12: Pair of White Storks (Ciconia ciconia) on a safe roosting site: the insulated conductor cable is attached directly to the pole. Germany Photo: W.Feld

Fig. 13: Low-voltage powerline with resting pigeons (Columba livia domestica): the conducting wires are arranged on one level (which is favourable). Because of their high electric resistance, birds are not at great risk of electrocution. Note: on medium-voltage powerlines the voltage is a factor 100 x higher. Germany. Photo: D.Haas

Fig. 14: Mammals, unlike birds, can easily be killed by electrocution already on low-voltage powerlines, because of their low electric resistance. In tropical countries, large bats (flying

foxes) are often seen hanging dead on low-voltage powerlines with particularly closely spaced conducting wires. Gambia Photo: D.Haas

Fig. 15: Typical “killer poles” are widely in use in most parts of the world – also in the Near East, where this White Stork (*Ciconia ciconia*) was electrocuted during migration and remained hanging. Photo: G.Fiedler

Fig. 16: A “killer pole” with very short upright insulators in China. Photo: D.Haas

Fig. 17 – 21: Dangerous medium-voltage power poles in Germany with electrocuted birds still hanging:

Fig. 17: Scorched Buzzard (*Buteo buteo*) on a metal pole with too short suspended insulators and with protective gaps (arcing horns) on top. The white plastic rods installed as bird rejectors do not correspond to the recommended technical standard. Photo: D.Haas

Fig. 18: Pole made of pre-stressed concrete with short suspended insulators and arcing horns. The Carrion Crow (*Corvus corone corone*) could easily reach the grounded arcing horn from its perching place. Photo: P.Havelka

Fig. 19: Buzzard (*Buteo buteo*) on a pole of pre-stressed concrete and with very short suspended insulators, without arcing horns. Today, longer suspended insulators are required in Germany (at least 60 cm isolation from perching site). Photo: G.Fiedler

Fig. 20: This Switch Tower made of pre-stressed concrete offers many dangerous possibilities for electrocution: shown is an electrocuted Eagle Owl (*Bubo bubo*) with its prey, a Carrion Crow (*Corvus corone corone*). Photo: D.Haas

Fig. 21: When old and wet, wooden poles do not insulate sufficiently and birds can be electrocuted like this Buzzard (*Buteo buteo*). Photo: K.F. Gauggel

Fig. 22: Very short insulator on a transformer of a medium-voltage tower station with an electrocuted Starling (Sturnus vulgaris). Denmark. Photo: G.Fiedler

Fig. 23: Tower station on a wooden pole with upright insulators (non-linear resistance arresters) and short distances between phases. Below we found an electrocuted Turkey Vulture (Cathartes aura). USA Photo: D.Haas

Fig. 24: Plastic Great Horned Owl unsuited for bird protection. This California Gull (Larus californicus) was not deterred. USA Photo: D.Haas

Fig. 25 a: Migrating White Storks (*Ciconia ciconia*) have found a safe roosting place on a medium voltage power pole (pre-stressed concrete pole with large suspended insulators). No casualties during the night; the storks continue their migration on the next morning. Germany Photo: G.Fiedler

Fig. 25 b: White Stork (*Ciconia ciconia*) on a similar relatively safe pole of metal with long suspended insulators. Spain. Photo: R.Schneider

Fig. 26: Long-Legged Buzzard (*Buteo rufinus*) on a safe medium-voltage power pole made of pre-stressed concrete with long suspended insulators. This safe construction is seen quite often in France and in North Africa. Tunesia Photo: D.Haas

Fig. 27: Unfortunately, we saw on our trips, that typical “kiler poles” are increasingly being used in France and North Africa. Tunesia 1995.   Photo: D.Haas

Fig. 28: Such “killer poles” cause electrocution casualties, such as this Long-Legged Buzzard (Buteo rufinus) with a talon died-off. Tunesia   Photo: D.Haas

Fig. 29: Two medium –voltage powerlines serving the same purpose: bird-safe powerline with suspended large insulators beneath powerline with “killer poles”. Unfortunately, “killer poles” are still in advance! Poland   Photo: D.Haas

Fig. 30: Medium voltage power pole with unfavourable multi-level arrangement of the cables, and thin neutral cable on top, with resting Carrion Crow (Corvus corone corone). The suspended insulators on the right side comply with the technical standards, those on the left side are too short. Germany   Photo: D. Haas

Fig. 31: Medium-voltage power line of the railways: pole construction which is relatively safe for large birds. The top of the pole is more than 60 cm above the energized parts. It is a safe perching site.   Sweden   Photo: G.Fiedler

Fig. 32: Medium-voltage powerline of the railways: safe and dangerous types of poles are used next to each other. In front a safe pole with sufficiently elevated top. In the background the tops of the poles are low – less than the required safety distance of 60 cm. The small plastic rods mounted on both sides of the insulators are ineffective for the safety of large birds. Germany   Photo: D.Haas

Fig. 33: Two safe and one dangerous power pole of the railways (too low top on the right-hand pole). Germany   Photo: D.Haas

Fig. 34: On this unsafe power pole of the railways, a pair of White Storks (Ciconia ciconia) attempted to breed (see deposited twig). Both birds died by electrocution on this pole. Germany   Photo: W.Feld

Fig. 35: Electrocuted House Crow (*Corvus splendens*) on the electric feed cable of a railway power pole with too short insulators attached from the side. India   Photo: D.Haas

Fig. 36: High voltage Tower, cables attached at 4 levels. In vertical direction, this construction obstructs a maximum of air space. On the thin neutral cable, marker spheres are mounted for air safety. Switzerland.   Photo: U.Glutz von Blotzheim

Fig. 37: High voltage tower, conductors attached at two levels. On the neutral cable high on top, a Common Gull (*Larus canus)*, had collided and the broken wing became twisted around the cable. Note the perching deterrents above the insulators. They are shaped as a closed wire construction. Their risk of injuring landing birds is less than that of the commonly used upright “whisk brooms” (Fig. 42). Sweden   Photo: G.Fiedler

Fig. 38: High voltage tower with favourable single-level arrangement of the conductor cables. Neutral cable only slightly above the conductor cables. 4 Ospreys (*Pandion haliaetus*) roost next to their nest. This type of construction was quite often built in former East Germany. Germany   Photo: D.Haas

Fig. 39: Maintenance work on an East-German high-voltage tower. Note the length of the insulators. Even large birds cannot span this length. Germany Photo: D.Haas

Fig. 40: High voltage powerline without neutral cable. This construction is found often in France and in North Africa. The Conductor cables are arranged almost at one height. This tower was painted for air safety in day light. France Photo: D.Haas

Fig. 41 : High voltage power line without neutral cable and with all conductor cables at one height. This single-level configuration minimises collision risks. Note the technical armatures, which replace the neutral conductor. France Photo: D.Haas

Fig. 42 : Upright « whisk broom » above the insulator suspension shall deter birds from landing and perching. Droppings with urination from large birds onto the insulators shall be avoided. A better technical solution is shown in Fig. 37. Switzerland Photo: D. Haas

Fig. 43: In familiar surroundings, cormorants can even use the thin cables of low voltage powerlines for perching. However, on their migrations they often collide with different types of powerlines near water. Double-Crested Cormorants (Phalacrocorax auritus). USA Photo: D.Haas

Fig. 44: Spiral with hanging plastic flap on the neutral cable of a high-voltage powerline. Spaced every 5 m, these markers can reduce collision casualties by 50 – 85 percent. For large birds, like swans, flap length should exceed 40 cm, while flaps of 20 cm proved already effective for the shelter of smaller birds like doves and pigeons. Germany. Photo: G.Fiedler

Fig. 45: Crows flying over neutral cable with markers as shown in Fig. 44. Germany Photo: G.Fiedler

Fig. 46: Markers on cables should be of simple and safe construction. A Little Egret (Egretta garzetta) became trapped in a spiral marker during a landing attempt. Spain. Photo: D.Haas

Fig. 47: Round markers on a medium voltage power line. Sweden Photo: G.Fiedler

Fig: 48: Detail of Fig. 47. Sweden Photo: G.Fiedler

Fig. 49: Medium-voltage powerline with spheres (better visibility at daytime) and suspended insulators, attached for air safety and here in particular for the safety of swans. Germany Photo: G.Fiedler

Fig. 50: Barbed wire fence of a pasture. Where the barbed wire crossed a small canal stream, a Green Heron (*Butorides striatus*) collided and became hanged. Barbed wire across bodies of water should generally be replaced by beams. USA Photo: D.Haas

Fig. 51: Unused barbed wire. Previously pasture, now nature conservation area. Birds of prey and field birds are still at risk of collision. All unused wires should be removed with priority. Germany. Photo: G.Fiedler

Fig. 52: Blackbird (*Turdus merula*) which was virtually decapitated by a thin-wired forest fence. Birds of endangered species, like grouses and woodcocks, regularly die in these fences. Germany Photo: D.Haas

Fig. 53: Construction work on a medium voltage powerline with very closely spaced phases (cables). It is essential that construction companies are made familiar with bird safety requirements and responsible for their implementation. Tunesia Photo: D.Haas

Fig. 54: Retro-fitting of a very dangerous Switch Tower. Germany. Photo: G.Fiedler

Fig. 55 Bird-safety provisions on a "killer pole". Initially mounted armature for bird protection (reflecting glass sphere and plastic deterrent rods) remained ineffective. After improved legislation, well-designed insulator hoods of 1,30 m length were installed and provide good bird-safety. Germany Photo: G.Fiedler

Fig. 56: "Killer pole" made safe with 1,30 m long insulator hoods, with Carrion Crow (Corvus corone corone). Germany Photo: D.Haas

Fig. 57: "Killer poles" made safe; cables at multiple heights. As required by German technical standards, all upright insulators were made safe with insulator hoods over many kilometres of the powerline. Germany Photo: D.Haas

Fig. 58: White Storks (*Ciconia ciconia*) on migration roost on an "ex-killer-pole", a metal tower station. The very dangerous upright insulator was reliably insulated with a protective hood. Protective hoods now are left open on the bottom (like here), in order to avoid lightning damage to the insulator material. Germany Photo: G.Fiedler

Fig. 59: This "ex-killer-pole" (metal construction) was reliably made safe by a change of construction. The cable in the middle was previously supported by an upright insulator on the top of the pole. Now this cable hangs suspended at the same level as the other cables. This single-level arrangement has the added advantage, that the risk of collision is also reduced. Germany Photo: G.Fiedler