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

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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 powerlines. Worldwide, this „wiring“ of the landscape 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 is assumed to be more than 50 years.

This report reviews the extent of the three main types of risk to birds from above-ground powerlines:

- **risk of electrocution:** Birds sitting on power poles and / or conducting cables are killed if they cause short circuits (short circuit between energised wires, 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 bird suffer heavy losses to electrocution, some species even being threatened with extinction as a result [20, 23, 76, 77, 83, 108, 134, 209, 255] (see section 4.1).
- **risk of collision:** In flight, birds can collide into the cables of powerlines because cables are often difficult to see. In most cases the impact of collision leads to immediate death or to fatal injuries and mutilations [86, 111, 124, 125, 134, 137, 174] (see section 4.2).
- **Reduction in availability for birds of staging and wintering areas:** mainly when above-ground powerlines cut across open landscapes and habitats (wetlands, steppe, etc.) [29, 83, 85, 124, 125] (section 4.3).

These topics are dealt with in a large number of reports and publications from all continents. In Germany, the Working Group „Birds and Powerlines“ of NABU (German Society for Nature Conservation, BirdLife Partner Germany) 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 at a national level.

In various parts of the world, different technical solutions for bird safety are under test and evaluation - thus 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-artregarding bird safety and 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 large bird species, 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 as far as possible. 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 or 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 damage.

According to current knowledge and experience, it is possible to reduce the risk of electrocution significantly, within acceptable costs for the electric utility companies. This can be achieved by observing the essential recommendations and construction criteria / principles for bird safety, as summarised in this report. This applies for new constructions and for retro-fitting kits. National governments 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. The recommendations of this report therefore have general, international validity. The catalogue of technical solutions for bird safety and medium-voltage power poles, as shown in this report has already been accepted by the states of the Convention on Migratory Species in September 2002[(55)].

The Bern initiative includes these technical solutions relative to the medium-voltage power poles. Additionally this initiative refers not only to all voltage ranges within the electrocution problem (including powerlines of railways), but also to the collision risk for birds, and the impact of powerlines on habitat qualities, mainly of staging and wintering areas.

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, suffer heavy losses. For some of these species, these continuing losses endanger their populations (see Table 1).

In Table 1 the severity of the impact on populations 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 to the bird population

II - regionally or locally high casualties; but with no significant impact on the overall species population

III - casualties are a major mortality factor; threatening a species with extinction, regionally or on a larger scale.

Table 1:
Severity of impact on bird populations of mortality 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 damage caused by bird accidents

In most cases, accidents on over-ground powerlines lead to severe injuries or immediate death. **Electrocution** mostly harms birds sitting on the ground rail or having ground contact. Current passage through the body causes damage to tissues and impaired functions: muscles and nerves abruptly stop functioning. The bird will fall from the pole and crash onto the ground, leading to 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. In rare cases, collision and electrocution occur at the same time, when two closely spaced conductors are shorted by the bird.

Table 2:

Typical primary injuries and secondary damage to birds caused by electrocution and collision. (Note: Only a small number survive these 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
Damage to plumage	burn marks: small, well-defined burn holes in the plumage; in case of discharging by an arc: large parts of plumage are burnt	mechanical damage, 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 damage to extremities	large necrotic areas on the limbs affected by current flow (largely or 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 damage by limbs dying-off	state of shock; handicapped by injuries and secondary damage

The technical installations of the powerline can be damaged from bird accidents: collisions can cause conductor cables to sever or to strike together. Short-circuits to ground can damage insulators (see Fig. 3) and switches. Bird accidents can lead to outages and economic damage.

- Birds that are set on fire by electrocution or arcing, can set off forest fires. This is a frequent cause of fires in hot climates like the Mediterranean, but also in temperate and arctic climates during dry summers.
- Bird accidents on the medium-voltage network of railroads can lead to traffic interruptions, associated economic damage, and inconvenience for the passengers.
- On high-voltage powerlines too, short-circuits can cause outages: short-circuits can be 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 helicopters will also be reduced.

4. Extent of risk to birds from electricity transmission facilities

4.1. Electrocution

Birds are attracted to power poles, just as they are attracted to large dead trees in the open countryside. 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 powerlines, numerous species of large birds suffer severe losses. Field research and investigations on storks, vultures, eagles and eagle owls have shown that these losses alone can drive species into decline and towards extinction[20, 45, 69, 77, 87, 108, 113]. „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.

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 6.2.1)
- retrofitting the existing „killer poles“ in accordance with recognised technical standards (see chapter 6.2.1).

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 especially small, if only very short upright 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. 10). Even songbirds can burst into flames, when electrocuted, and can ignite wild fires and / or forest fires.

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 within which they can die and they are quickly taken away by raptors, foxes, badgers and other scavengers. It was not until ringing programs and the analysis of ring recoveries, and the monitoring of birds fitted with radio transmitters, that the disastrous toll due to electrocution was revealed.

On their migration routes, numerous species of large birds suffer substantial mortality from electrocution. For example, White Stork (*Ciconia ciconia*) banding programs have shown that electrocution along the European migration routes of the White Stork represent the main cause of death.

At certain locations, remarkable numbers of dead birds have been 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 four Eagle Owls (*Bubo bubo*) and 3 Kites (*Milvus milvus* and *Milvus migrans*).

In a staging area in Kazakhstan, 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 1 Black Vulture (*Aegypius monachus*).

„Killer poles“ in prime habitats for large birds logically lead to the highest losses of large birds. In these habitats, measures for bird protection, such as making „killer poles“ safe, have the greatest effect. This includes man-made habitats that are very attractive to large birds, for example, White Storks winter in increasing numbers on large garbage dumps like those in southern Spain.

4.2. Collisions

In principle, birds of any flying species can become victims of collisions with some types of aerial wire or cable: this includes telephone / telegraph linesas 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, cranes, waterfowl and sandgrouses.

Fortunately, many types of electric lines will be removed with 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 of 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 replace 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 is already under-ground. In addition the low-voltage overhead powerlines continue to be replaced underground.

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, have been performed on high- and highest-voltage powerlines[3, 18, 28, 29, 34,90, 101,104, 105, 115, 124, 125, 134, 150, 170]. 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 in one year. 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].

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. Flight manoeuvres, which can lead to collisions with cables and wires, are observed more often from migratory birds, than from resident birds.

Especially in the case of rare species, collision losses can represent an additional, substantial mortality factor [48, 58, 124, 125, 134, 140,174, 175, 179, 194].

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 powerline (see also chapter 6.2.2).

High risk potential can be stated for:

- areas of high avifaunistic importance including with high bird populations and a high percentage of migratory birds, especially during migration; particularly high losses are reported where powerlines cut across important flyways and migration corridors, such as river valleys, valleys between mountains, straits, etc.

- wetlands, marshes, coastal areas, steppes, especially in staging and wintering areas, in particular when above ground powerlines separate resting areas and feeding areas or are otherwise in the flight approach of important staging and feeding areas, in particular close to water; powerlines thus, in effect, degrade the quality of staging and wintering habitats.
- migrating birds, when powerlines are perpendicular to their flight path
- birds migrating at night are at highest risk.

Influences and conditions that increase the risk of collision:

- any disturbances leading to panic flight movements (as often caused by hunting)
- bad visibility of conductor cables, which are coated with aluminium oxide (grey coloured)
- unfavourable weather conditions, like fog, precipitation, strong head winds; these conditions tend to concentrate bird migration at a lower height – often level with overhead cables, as well as reducing visibility and manoeuvrability of flying birds.
- most collision accidents happen during the night and during dawn and dusk.

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. There are an estimated 500,000 to 1,000,000 collision casualties per year. Up to 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 casualties were reduced by 185,000 birds per year.

4.3. Reduction of availability of areas for birds as staging and wintering areas

Above-ground powerlines increase the mortality rate of birds of the open habitats, like steppe, meadowlands, marshes, etc, not only from electrocution and collision but also by increased predation levels (as the casualties under the powerlines attract mammalian predators and provide perching sites and lookouts for birds of prey).

Above-ground powerlines can lead to the loss of useable feeding areas in staging and wintering habitats, for example feeding arctic-breeding geese have been observed to avoid the close vicinity of powerlines in their wintering areas [(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 and 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 for conservation must be carefully weighed and traded.

5. Different types of electricity transmission facilities and their risks to birds

The basic types of pylons and poles from overhead lines are very similar worldwide. In most countries many different types exist, often very different from company to company.

5.1. Low-voltage powerlines

In a number of countries, all or most of the low-voltage supply lines are routed under-ground, which is the best solution for bird safety. Often, low-voltage supply lines use well-insulated cables, directly attached to support poles (see Fig.4), which is the second-best solution. Collision risk is minimised, because the clearly-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. However, climbing and flying mammals (which have a low electronic resistance) 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). 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. 4).

Low-voltage powerlines have a voltage 100 times less than those of medium-voltage.

5.2. Medium-voltage powerlines

5.2.1. 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 still have 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. 3, 5, 6, 7, 8, 9, 13, 14 and 15). Such „killer poles“ are a large danger to many species of large birds in most parts of the world.

Closely spaced conductors, less than 1.40 m apart, are often the cause for fatal short-circuits, when birds touch both conductors simultaneously. Such short distances between conductors of different phase are often seen on Switch Towers (see Fig. 8).

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 (Fig. 15). They should be removed for bird safety reasons.

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. 11 a and b, 12, 14).

5.2.2. 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: both bird-safe solutions (Fig. 16) and„killer poles“ (Fig. 18) are in use, sometimes right next to each other (Fig. 17). 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.

5.3. High-voltage powerlines

High-voltage powerlines are almost exclusively above ground. Because of their long suspended insulators, the risk of electrocution is low (Fig. 21). 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. 20, 24).

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/or with neutral cables high above the conductor cables (Fig. 2, 19, 20).

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). These constructions 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 (Fig. 22, 23).

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 which otherwise have high collision risk constructions:

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

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

For bird safety on existing powerlines and new ones which are still being erected with the neutral cable high above the conductor cables, the thin neutral cable should be made clearly visible by suitable markers. Such provisions can reduce collision accidents by 50 to 85 percent, as most collisions occur with the thin neutral cable. At close range, birds recognise the relatively thick conductor cables and perform obstacle avoidance manoeuvres that can lead to them crashing into the thin neutral cable.

As markers for better visibility of the neutral cable, vertically hanging black and white plastic oval flaps, which flash and rotate in the wind, have recently been shown to provide the most effective, but are not yet used. Often plastic spirals are used (Fig. 25 shows devices on high voltage, fig. 26 on medium voltage powerlines), which can be dangerous in other ways. In any case, warning provisions are inevitably less effective than the removal of the neutral cable high above the conductor cables.

6. Recommendations and guidelines

6.1. Experience from conservationists' work

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, obstructing the air space and thus bird migration routes with multiple levels of cables.

Voluntary agreements between electric utility companies and conservationists are rare. Where good co-operation has been achieved, the results have so far been at local or, at most, regional level, eg the replacement of some extremely dangerous „killer poles“. Overall, the effect of such efforts has been negligible, in particular where „killer poles“ remain in place and continue to be constructed.

The responsibility of the electric utility companies to observe bird safety is in the public interest and is also a matter of ethics. However, satisfactory implementation of state-of-the-art of bird safety provisions depends on clear and unambiguous legislative action.

The experience of several countries is that 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.

6.2. Technical Standards

6.2.1 Standards to protect birds from electrocution

Technical standards are recognised and binding design guidelines exist for the construction of powerlines. These technical standards should contain a special 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“.

In Germany the introduction of a Bird Protection Clause was an important requisite to ultimately removing „killer poles“. The wording of the Bird Protection Clause in the German Industry Norm (DIN VDE 0210/12.85) is the following:

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

The technical measures (regionally) taken in accordance with these technical standards since 1985 have already had 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. Further positive effects are expected now from the new German legislation act.

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 (Comments on Section 8.10 Bird Protection of German Industry Norm VDE 0210/12.85).

The new Paragraph 53 “Bird Protection on powerlines” 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.(…)”*

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

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 report 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).

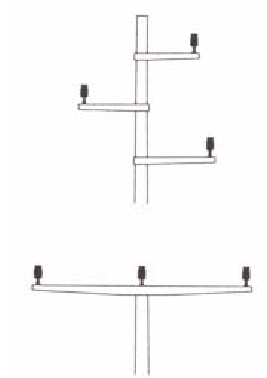
The safety of the installations depends primarily on

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

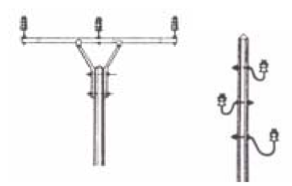
A) POWER POLES WITH UPRIGHT INSULATORS

Power poles, constructed on pre-stressed concrete or metal 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.

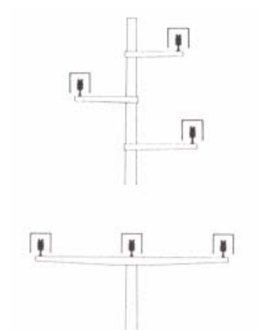
Risk: high



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

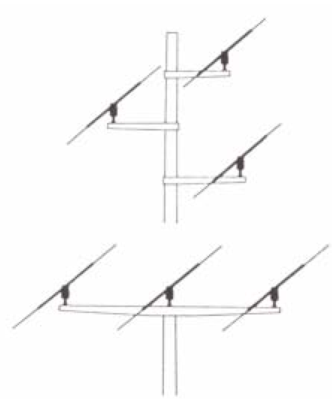


Mitigating electrocution effectively is possible either by treating poles (a) with insulating caps made of plastic for outdoor use 130 cm in length or (b) insulating powerlines with tubing 130 cm in length. The conductors have to be spaced at a distance of at least 140 cm. If this is not possible, they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



Suggested Practices:

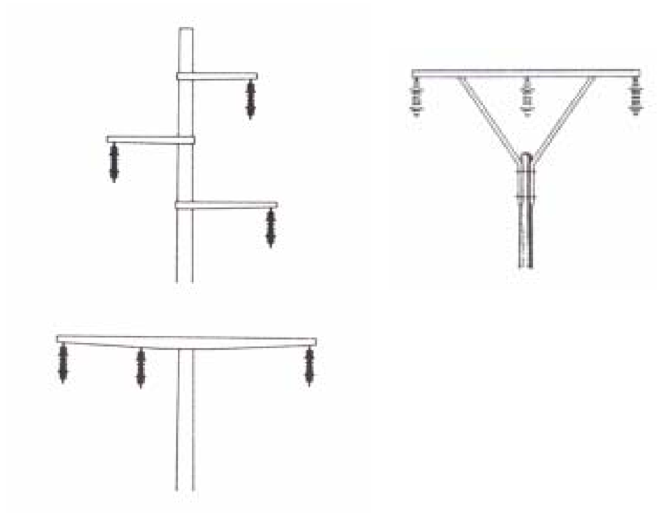
(a) Insulated caps (above)
(b) Tubing (below)



B) 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.

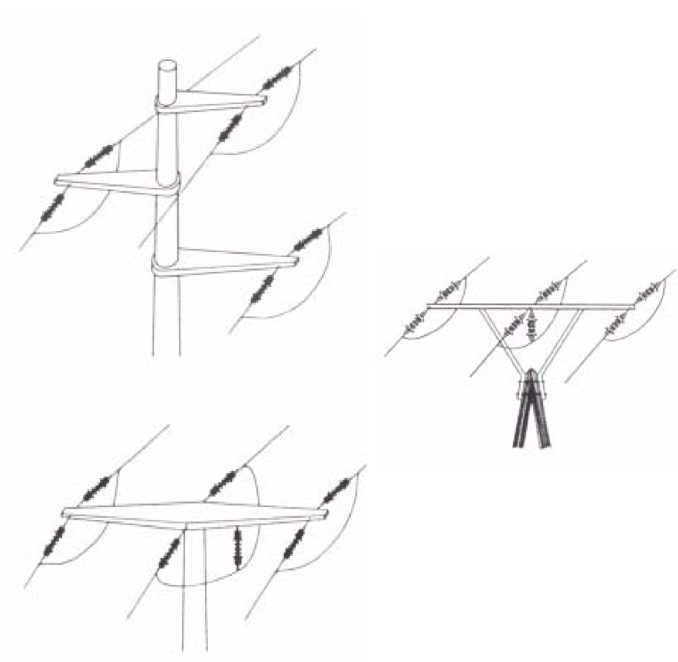
Risk: low



(C) STRAIN POLES

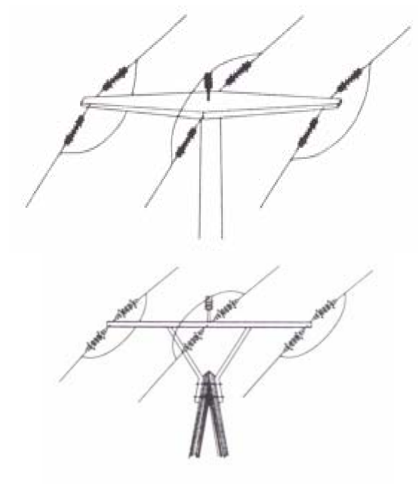
Strain poles with powerlines <u>below</u> the crossarm:

Risk low, if the insulators are long enough (at least 60 cm).



Strain poles with one conductor above the crossarm.

Risk high (see also Fig. 3):

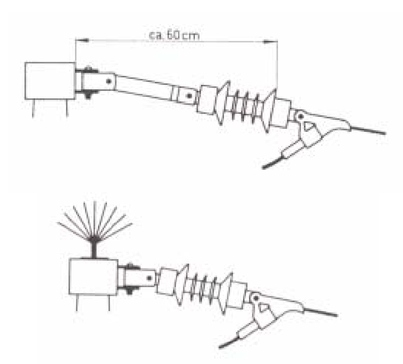


Bird-safe strain poles require insulating chains at least 60 cm in length. Hazardous constructions can be mitigated by
(a) lengthening the chains or
(b) installing perch rejectors (upright “whisk brooms”) on the crossarms.

Suggested practices:

Lengthening of the chain (a, above)

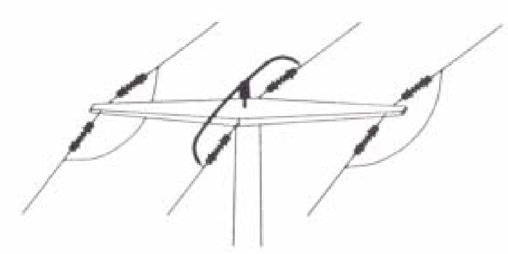
Perch rejectors, made of plastic rods (b, below)



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 (insulation of conductors which come too near to a perching site – closer than 60 cm).

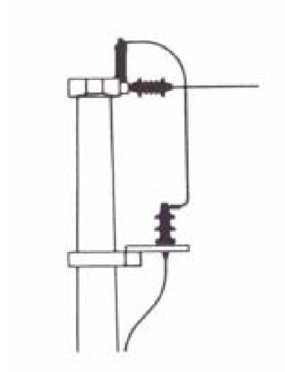
Suggested practices:

Insulated hood or insulated tubing (c)
(see also Fig. 30)

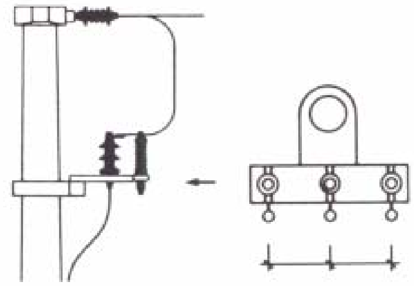


D) TERMINAL POLES AND TOWER STATIONS

Terminal pole



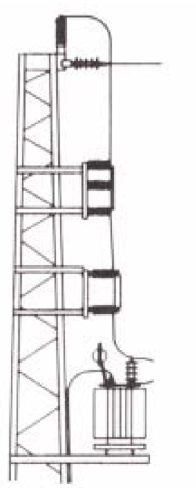
Risk: high



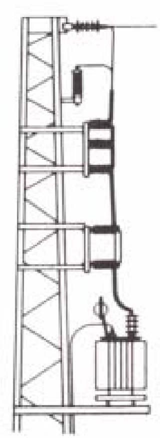
Suggested practices (see legend)

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 down leading wires are insulated with tubing. On tower stations all contacts directly above the switch as well as between the switch and transformer should be treated likewise. Hardware used to prevent electrical arcs should not be used (mitigation measure : dismantle).

Tower Station



Risk: high

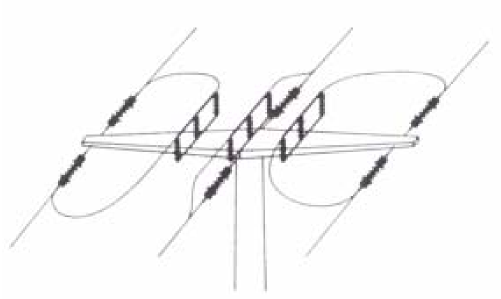


Suggested practices (see legend)

E) 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.

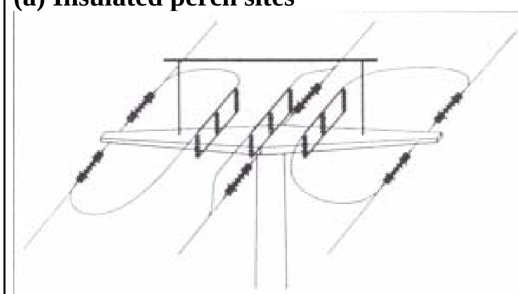
Switch tower



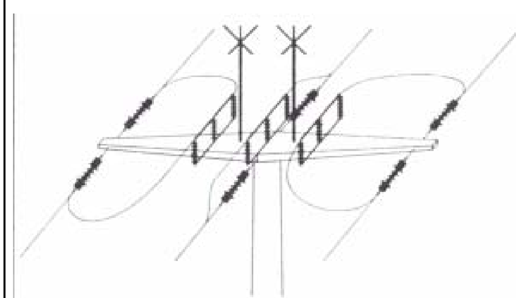
Risk: high

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).

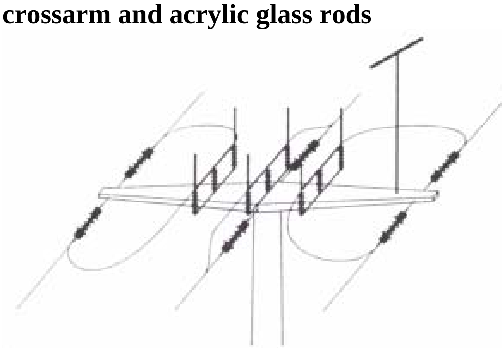
Suggested practices:
(a) Insulated perch sites



(**b) St. Andrew`s Cross**



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



In the case of medium-voltage **railway powerlines** , 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. 16 illustrates that bird safety can be introduced without large technical effort.

6.2.2 Standards to protect birds from collisions

For the safety of air traffic and for the minimisation of fatal bird collisions with powerlines, the following requirements must be applied to all 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 cover bird migration at day and night time and other seasonal phenomena.
- 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.
- Infrastructures shall be bundled, where possible, e.g. powerlines to be routed along roads and railways, in order to maintain open unfragmented landscapes.
- 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.
- Attachment of clearly-visible black-and-white markers on cables posing a high collision risk, in particular the neutral cable of high-voltage powerlines
- 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.
- 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.

6.3. 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 of brought about the necessary changes. World-wide the first state to implement these regulations was the German state of Baden-Wuerttemberg, through passing of legislation in 1991 (see also legend of front cover photo).

In all 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“ cannot be resolved satisfactorily. For example, typical „killer poles“ are still erected both in Europe and 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 (UNEP) that guidelines should be issued, comparable to those of the WHO on medical matters. Beyond the electrocution problem, these guidelines should also include the recommendations made with respect to collision avoidance on powerlines.

6.4. Further research

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

At regional and local level, a large need exists for ornithological investigations prior to 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. Materials used 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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9. Legend to the Figures

Fig. 1 (front cover photo): 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-Wuerttemberg 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-Wuerttemberg having been absent for almost 100 years. Also the Eagle Owls have increased their range now occupying suitable habitats throughout Baden-Württemberg. Photo: D.Haas

Fig. 2: 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. 3: This insulator damage was observed, after five crows had been electrocuted at this site. Germany Photo: D.Haas

Fig. 4: 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. 5 – 9: Dangerous medium-voltage power poles in Germany with electrocuted birds still hanging:

Fig. 5: 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. 6: 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. 7: 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. 8: 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. 9: 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. 10: Very short insulator on a transformer of a medium-voltage tower station with an electrocuted Starling (*Sturnus vulgaris*). Denmark. Photo: G.Fiedler

Fig. 11 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. 11 b: White Stork (*Ciconia ciconia*) on a similar relatively safe pole of metal with long suspended insulators. Spain. Photo: R.Schneider

Fig. 12: 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. 13: Unfortunately, we saw on our trips, that typical "killer poles" are increasingly being used in France and North Africa. Tunesia 1995. Photo: D.Haas

Fig. 14: 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. 15: 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. 16: 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. 17: 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. 18: 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. 19: 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. 20: 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. 21: 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. 22: 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. 23 : 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. 24 : 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. 25: 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. 26: 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. 27: Retro-fitting of a very dangerous Switch Tower. Germany. Photo: G.Fiedler

Fig. 28 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. 29: “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. 30: 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. 31: 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

ANNEX: Fig. 1 – 31

[separate file]