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GUIDELINES FOR MITIGATING CONFLICT BETWEEN MIGRATORY BIRDS AND ELECTRICITY POWER GRIDS

(As adopted by the 5th Session of the Meeting of the Parties to the Agreement on the Conservation of African-Eurasian Migratory Waterbirds/AEWA)

AGREEMENT ON THE CONSERVATION OF
AFRICAN-EURASIAN MIGRATORY WATERBIRDS

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"Migratory waterbirds and people - sharing wetlands"

DRAFT GUIDELINES ON HOW TO AVOID OR MITIGATE IMPACT OF ELECTRICITY POWER GRIDS ON MIGRATORY BIRDS IN THE AFRICAN-EURASIAN REGION

Introduction

The German energy company, RWE Rhein-Ruhr Netzservice GmbH (RWE RR NSG) and the UNEP/AEWA Secretariat signed a partnership agreement at the 37th Meeting of the CMS Standing Committee (Bonn, 23-24 November 2010). As part of this agreement, RWE RR NSG provided funding for the preparation of an independent review on the conflict between migratory birds and electricity power grids in the African-Eurasian region and the development of guidelines for mitigating and avoiding such a conflict.

At the end of 2010, the UNEP/AEWA Secretariat, also on behalf of the Convention on Migratory Species (CMS) and the CMS MoU on Birds of Prey, commissioned the preparation of the review and the guidelines to an international consortium of expert organizations. Both papers were elaborated by a team led by Hein Prinsen of Bureau Waardenburg, which also included the Boere Conservation Consultancy, STRIX Ambiente e Inovação and the Endangered Wildlife Trust (Wildlife & Energy Programme).

These guidelines offer various technical and legislative approaches for avoiding or mitigating the impact of electrocution and collision of migratory birds across the African-Eurasian region as well as suggestions for assessing and monitoring the effectiveness of mitigation and preventive measures.

The draft guidelines were consulted with the AEWA Technical Committee (TC) at its 10th Meeting in September 2011 and by correspondence with the CMS Scientific Council (ScC). Their final version was approved by the TC in November 2011 by correspondence and by the ScC at its 17th Meeting in November 2011. The guidelines were noted by the 10th Conference of the Parties to CMS in November 2011.

Action requested from the Meeting of the Parties

The Meeting of the Parties is invited to review and adopt these guidelines as Conservation Guidelines in the sense of Article IV of the Agreement (draft Resolution AEWA/MOP5 DR10 *Revision and Adoption of Conservation Guidelines*).

DRAFT GUIDELINES ON HOW TO AVOID OR MITIGATE IMPACT OF ELECTRICITY POWER GRIDS ON MIGRATORY BIRDS IN THE AFRICAN-EURASIAN REGION

November 2011

Funded by AEWA's cooperation-partner, RWE RR NSG, which has developed the method for fitting bird protection markings to overhead lines by helicopter.

VORWEG GEHEN

Produced by
Bureau Waardenburg
Endangered Wildlife Trust – Wildlife & Energy Program
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Milestones in the production of these guidelines
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Final draft: November 2011, approved by the AEWA Technical Committee in November 2011 by correspondence, the 17th Meeting of the CMS Scientific Council on 17-18 November 2011 in Bergen, Norway, the 10th Conference of the Parties to CMS on 20-25 November 2011 in Bergen, Norway, and the 7th Meeting of the AEWA Standing Committee, 26 - 27 November in Bergen, and presented to the 5th Session of the Meeting of the Parties to AEWA on 14-18 May 2012 in La Rochelle, France.

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Picture on the cover: Installation of bird flight diverters by helicopter in high voltage power line

CONTENTS

Step Chart

To minimise the effects of power lines on birds, each country should take the following steps:

Step 1: Develop and support strategic long term planning of nationwide electricity grid networks, including putting low to medium voltage power lines below ground. Apply appropriate Strategic Environmental Assessment (SEA) procedures for decisions on the need of power lines on a national scale and apply similar appropriate Environmental Impact Assessments (EIA) procedures on the construction of a power line once it has been decided that such a power line is needed. Aspects of the risk for bird collision and electrocution should be integrated into the EA procedures.
For more details on how to apply SEA and EIA procedures we refer to AEWA Conservation Guidelines No. 11 (2008): *Guidelines on how to avoid, minimise or mitigate impact of infrastructural developments and related disturbance affecting waterbirds*; AEWA Technical Series no.26.

Step 2: Develop and support collaboration between all stakeholders (utility companies, conservationists, governmental organisations) through support of Memoranda of Understanding on a volunteer basis, for example, or, if necessary, impose the cooperation of utility companies for strategic planning and mitigation of negative effects on birds through legislation.

Step 3: Develop scientifically based databases and spatial datasets on the presence of protected areas and other key bird areas and presence of susceptible bird species, including flight routes of these species between breeding, feeding and resting areas as well as important migration corridors. These datasets enhance strategic planning in steps 1 and 2 and define priorities in step 4. If no data are available, such as from regular national bird monitoring projects, then field data must be collected for a minimum of one year.

Step 4: Routing new above ground power lines away from key areas for birds, taking into account the presence of protected areas (with either a national or international status), abiotic factors that influence the bird/power line conflicts and the susceptibility of relevant bird species.

Step 5: Develop priority lists of key conservation areas and species in order to identify priorities for mitigating sections of new power lines and retrofitting existing power lines.

Step 6: Mitigate problematic sections of power lines, both existing and planned, to minimise the effects of electrocution and collisions on birds by using state-of-the-art techniques.

Step 7: Develop and support evaluation programs that use standardised protocols to monitor the effectiveness of mitigation measures as well as to improve mitigation techniques, including monitoring of incidents (electrocution and collision) and the presence and movements of birds in order to assess the (species-specific) scale of impact.

1. Introduction

Because of their size and prominence, above ground electrical infrastructures represent significant risks for birds if certain precautionary measures are not taken. Most above ground power lines (both medium voltage distribution lines and medium to high voltage transmission lines) present potentially fatal risks for birds through risks of collision with overhead wires and the risk of electrocution. A bird collision occurs when a flying bird physically collides with an overhead cable. The bird is typically killed by the impact with the cable, the subsequent impact with the ground, or dies from the resulting injuries. Electrocution of a bird occurs when it bridges the gap between two energised components or an energised and an earthed (also-called 'grounded') component of the pole structure. This results in a short circuit, with electric current flowing through the bird's body, and electrocution, often accompanied by an outage of the electricity supply.

Power lines are one of the major causes of unnatural deaths for birds in a large part of the African-Eurasian Flyways with, for example, an estimated many millions of collision victims each year in Germany alone (Hoerschelman *et al.*, 1988). In several European countries a relative high proportion of collision victims involve endangered species of Appendix I of the Birds Directive, *e.g.* European Spoonbill (*Platalea leucorodia*) and Black-tailed Godwit (*Limosa limosa*) in the Netherlands, and bustards and eagle species in Spain and Portugal. The problem is also believed to be serious in Africa. In South Africa, for example, the survival of several critically endangered species, such as Blue Crane (*Anthropoides paradise*) and Ludwig's Bustard (*Neotis ludwigii*), is believed to be severely threatened due to collisions with power lines. Unfortunately, for most of the continent concrete data are missing.

Although nowadays electrocution is not much of a problem in Northwest Europe, where most of the lower voltage lines have been placed underground, there are still many countries, both in Europe and elsewhere along the African-Eurasian Flyways, where low and medium voltage lines have not been equipped with proper mitigating measures. In these countries electrocution poses a serious threat to a number of populations, in particular storks and raptors that build their nests on the electricity poles or use the poles as perches. There are indications that for certain bird species, particularly larger species, electrocution may be the most serious cause of death; even more than road traffic (Haas *et al.*, 2005). Electrocution of birds is not just a conservation issue, it also has serious economic and financial consequences due to the disruption to power supplies and thereby presents a cause for concern among electricity distribution companies.

Unfortunately, many electricity companies are not aware of, or are reluctant to apply, state-of-the-art bird safety provisions. Sensible changes to the routing of the power lines and changes to the structures (both marking overhead wires and modifications to avoid electrocution) can effectively reduce the risk posed to birds by 50 percent or more.

A large number of studies, including previous reviews, have been published on the issues involved. However, the information is scattered, not always easily accessible (much in internal reports and 'grey literature'), much is of anecdotal character and an overview of the magnitude of the conflict between birds and electricity power grids at the scale of the African-Eurasian region is lacking. The same applies for the solutions to avoid electrocution and various measures to mitigate collisions. Therefore, the secretariats of the Convention on the Conservation of Migratory Species of Wild Animals (UNEP/CMS) and the Agreement on the Conservation of African-Eurasian Migratory Waterbirds (UNEP/AEWA) commissioned a review of all aspects of the conflict between migratory birds and electricity power grids, and guidelines for mitigating and avoiding this conflict within the African-Eurasian region.

Because of the extensive information collated, the review of the conflict between migratory birds and the electricity power grids in the African-Eurasian region has been published in a separate document, published as CMS Technical Series No. XX and AEWA Technical Series No. XX titled 'Review of the conflict between migratory birds and electricity power grids in the African-Eurasian region' (Prinsen *et al.*, 2011a). The international report provides important background information to this guidelines document.
Guidelines on the conflict between birds and power lines have been published before, most notably the Convention on the Conservation of European Wildlife and Natural Habitats (the Bern Convention)

published detailed guidelines to be implemented for the protection of birds on medium voltage power lines, based on Haas *et al.* (2005), and the Bern Convention Standing Committee in 2004 adopted Recommendation No. 110 on minimising adverse effects of above ground power lines. Furthermore, in 2002 CMS/COP 7 adopted a resolution (No. 7.4 "Electrocution of Migratory Birds"), which called on Parties and Non-parties to implement technical and legislative measures to mitigate the electrocution of birds on power lines, based on guidelines published in a brochure by NABU (German BirdLife partner), which is a precursor of Haas *et al.* (2005). Also for North America, extensive practical guidelines are available, published by APLIC (1994, 2006).

The guidelines at hand and the accompanying International Review (Prinsen *et al.*, 2011a; UNEP/CMS/Inf.10.38) present the available information (including references to other reviews) on the topic from the wider area of the African-Eurasian region. These documents summarise the latest technical standards on electrocution mitigation and review and present guidelines to mitigate collision risk for birds, a topic that received less attention in both the guidelines of the Bern Convention and the 2002 CMS Resolution 7.4.

This guideline document presents appropriate actions, both legislative as well as technical, summarises the state-of-the-art mitigation/avoiding measures and gives suggestions for evaluation and monitoring. Detailed technical instructions on the construction of mitigation measures is outside the scope of these guidelines, for these we refer to existing technical literature and recommend APLIC (1994, 2006), Haas *et al.* (2005) and Haas *et al.* (2008) for more technical details on, for instance, construction techniques.

2. Strategic planning, legislation and organisational approaches

General aspects

Antal (2010) argues that policy factors have a significant effect on the effectiveness of mitigation measures. He surveyed four countries, Slovakia, Hungary, South Africa and the United States, in order to assess their approach to bird interactions with power lines. He concluded that the likelihood of success in managing the issue of bird/power line interaction depends very much on country specific contexts. To provide guidance on legislation to CMS and AEWA Parties is, therefore, not easy and cannot be too detailed or very straight forward given the great differences between countries in governance, decision-making structures and procedures and the complexity of the energy sector. Nevertheless, there are some basic principles and approaches that every country should apply.

Network planning

The most obvious way in which to prevent bird electrocutions and collisions is to avoid building the power line altogether. Whilst this may seem contrary to various social, political and economic imperatives throughout the world, most importantly in the developing world, it is theoretically possible to increase access to electricity whilst minimising the construction of new power lines. This can be achieved through efficient network planning and dispersed power generation options (*i.e.* power production close to end user). Generation and network planning are therefore the first step towards mitigating risks for birds. In the long term, energy efficiency measures and management of energy demand should also be components of the approach. The less electricity that is consumed, the less need there will be for the vehicles (power lines) to transport that electricity, and the less the electrocution and collision risk. Infrastructure utility companies typically conduct their long-term planning through the development of network master plans. If these master plans incorporate bird information, this can be a powerful tool for minimising the collision risk for birds at an early planning stage.

Underground power lines

If power lines must be constructed then burying the power lines underground offers the best solution against electrocution and collisions of birds. Although this has relatively seldom been implemented for any significant length of line, mainly due to the technical and financial challenges (estimated at 3 to 20 times more expensive – APLIC, 1994), it does appear that at least in certain parts of Europe, burying power lines is more widely practiced.

The process of placing low voltage utility and medium voltage distribution lines (those that pose the greatest electrocution risk to birds) underground has been completed in the Netherlands and is currently being carried out in Belgium, the United Kingdom, Norway, Denmark and Germany, and hence the severity of the electrocution problem is reducing in this region. At the beginning of the 1990s, 77% of the transmission lines in Belgium were already underground, 56% in (West) Germany and 44% in the United Kingdom (Bayle, 1999). In Denmark, a recent plan describes the decommissioning of the existing 3,200 km of 132-150 kV overhead lines and the cabling of around 2,900 km of new 132-150 kV lines. Although it is technically very difficult to underground high voltage power lines (*i.e.* over 110 kV), in Denmark a political decision has been made to immediately start a project to place selected sections of high voltage overhead lines (400 kV) underground in six areas of high natural value or in close proximity to urban areas (information from returned enquiry Denmark; V. Hørlyck *in litt*.). This not only provides advantages for bird protection, underground cables also have a higher tolerance to weather, greater public acceptance, and thus quicker authorisation, as well as greater reliability and no risk of causing forest fires. On the other hand, it is technically challenging to place high voltage power lines underground, and this brings about much higher investment costs. Nevertheless, this must be viewed in relation to the additional costs mitigation measures would cause at above ground lines. In Hungary, for example, laying cables underground is estimated to be 20 times more expensive (approximately US$ 54,000/km) than the use of bird flappers (a type of line marker) to mitigate collisions. On the other hand, Antal (2010) estimates that in Hungary at least US$ 7 million is spent annually in retrofitting existing power poles to mitigate electrocution.

Putting power lines underground clearly is the ultimate solution but will be far too costly for many countries or technically difficult in, for instance, mountainous regions. It is, therefore, unlikely to be widely used or contribute significantly to electrocution or collision mitigation within developing countries in the near future. It must also be noted that burying power lines may bring with it increased impacts on other components of the environment.

SEA and EIA procedures; secure the interests of birds in relation to power line constructions

In the first place careful Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA) procedures should be in place and applied. These procedures should look at a large number of possible effects on environment and nature of any decision on the construction of infrastructure, including power lines. The possible effect on bird population in whatever sense should be an obligation under any SEA and EIA procedure to be described and analysed.

The SEA is a means, by which environmental considerations are incorporated into policies, plans and programmes in order to achieve the best possible outcome for all involved. This is particularly effective with respect to power line routing and grouping, as appropriate corridors for lines can be identified proactively, well before reaching the individual project stage. The EIA process allows for the assessment of impacts at the project level. Although project based and fairly late in the power line planning process this still provides a useful and essential mechanism for minimising the collision risk for birds.

The response of the Range States to the enquiry makes clear that actually most countries have at least legislation to apply EIA procedures (the presence of SEA procedures was often not indicated). It is of course of importance how the procedures are applied and what aspects are included and weighed in the final decision-making. More detailed information on the SEA and EIA process and its benefits for birds can be obtained in the AEWA Conservation Guidelines No. 11, titled ‘Guidelines on how to avoid minimise or mitigate the impact of infrastructure developments and related disturbance affecting birds’(Tucker & Treweek, 2008).

Already at this early stage of the policy and decision-making, information on bird populations and migration routes should be collected from available sources or, if not present, collected in a programme of field research over a period of at least one year (see **chapter 6** and **appendix 1**). This would also substantially help to avoid any later conflict with national and international conservation legislation (see below) if strictly protected species are possibly going to be killed by the power lines through electrocution and/or collision.

The availability of bird data and presence of protected areas before or during SEA and EIA procedures cannot be emphasised enough. Appropriate routing of an above ground power line, including available bird data, can already substantially reduce the problem with bird interactions. Unfortunately, many developing countries may not have the resources to carry out detailed field research to collect relevant bird data. A facility should be made available that external funding can be provided to carry out basic survey work. For relative small projects project developers should cover and embed expenses of base-line studies in the project budgets. For more extensive power line construction programs, this could be facilitated by governments through National Development Agencies or international funds such as through the Global Environmental Facility (GEF). This should also work for countries that would like to replace and/or mitigate already existing dangerous power lines.

SEA, EIA procedures and national nature conservation legislation; prepare intra governmental arrangements.
The construction of basic energy distribution and supply infrastructure is vital for a country and its population. Countries may have legislation to assure that this is indeed secured. However, the construction and routing of a power line, after being subject to sound SEA and EIA procedures, may come in conflict with arrangements on habitat and species conservation. This can be the case, for instance, when a power line is planned to cross an important wetland or pass a forested area with important bird populations, *etc*.

In such cases, it is often not clear which legislation is overriding. It looks very obvious that for the government agencies responsible for different aspects, this should be clear from the beginning, but the reality may be different. For example, if the killing of any individual of a (vulnerable or endangered) species is forbidden under a bird conservation act or general wildlife act, how does this work in case power lines are killing such birds? Is the government agency providing permission for the construction responsible or the utility company and can they be fined? A fining procedure may not be applied and could be excluded well in advance through articles in legislation that create exceptions on the general conservation rules accepting that a power line is of overriding interest for the society. However, it has been under discussion (*pers. comm*. J. Smallie for South Africa and H. Prinsen for the Netherlands) and should be very clear for all those responsible.

It is for such reasons that some countries, the United States is one example, have worked on MoUs between the responsible ministries and/or agencies to describe in clear terms each other’s responsibilities and the way conservation legislation should be interpreted. To give an example: are all parties in agreement that if an endangered species is legally strictly protected, that such legislation then forces electricity companies to for instance re-route a planned power line, or bring a certain section underground, *etc*. This must be very clear given the precedents and high costs in cases were conservation aspects overrule the construction of a power line in that particular place. This apart from all type of mitigation measures on the power line itself, which can also be forced by legislation. It would be good policy to have such arrangements between the responsible ministries/agencies.

National legislation, utility companies and NGOs; prepare cooperative MoUs
Another step in the legislative and organisational approach of the conflict between power lines and birds is cooperation between government agencies and/or NGOs with the electrical utility companies on a voluntary basis as laid down in a Memorandum of Understanding (MoUs). Such cooperative MoUs between all stakeholders are often effective. Successful MoUs avoid legal procedures between various stakeholders and contain provisions on each other’s responsibility and contributions, both financially and also organisational (*e.g*., on raising awareness, monitoring and research). The South African experience (a state-wide cooperation between the single utility company Eskom and the Endangered Wildlife Trust to resolve problems of electrocution and collisions) is that a cooperative, partnership approach is the most effective. The first step by conservationists dealing with this issue should therefore be one of collaboration with the relevant utility companies, realising that energy supply is an overriding public interest. Similarly successful cooperation between electricity companies, government agencies and/or NGOs also exist in Germany, France, Hungary, Switzerland, Portugal, and Namibia (see **Box 1**).

BOX 1: Example of MoU between the Government, electricity companies and NGOs in Hungary
In Hungary, the Ministry of Environment and Water, all utility companies and BirdLife Hungary signed the 'Accessible Sky' agreement in 2008. Within this voluntary agreement, the following achievements have so far been made:

- Regular, structured cooperation (Coordinating Committee, defining and carrying out common projects, see below);
- Amendment of technical standards by joint effort and application by designers as well as permitting authorities (recommendations introduced in 2007 applied by designers in manuals and enforced by authorities, these have since been further amended and are to be published in 2011);
- Amendment of the Act on Nature Conservation (newly built or reconstructed power lines have to be bird-friendly);
- Database of priority power lines and bird casualties (BirdLife Hungary produced a conflict map depicting 21,700 kilometres of medium voltage power lines that are of priority for retrofitting to mitigate for electrocution and/or collision. Costs for retrofitting are estimated to exceed 60 million euros).

Both proactive and reactive actions are undertaken, with the goal to retrofit all lines dangerous for birds before 2020. So far, important results from this agreement include several LIFE Nature projects:

- Retrofitting highest priority power lines;
- Great Bustard project: 11 kilometres of line buried, 45 kilometres marked with FireFly markers;
- Saker Falcon project: 510 kilometres of line insulated;
- Red-footed Falcon project: 400 kilometres of line insulated.

Furthermore, decisions have been made on 10 retrofitting projects during 2008-2010. The total amount of investment is estimated at *ca.* 10 million euros. In January 2011 there was a call for new projects, in which 25% co-financing is required from electricity suppliers, based on their voluntary undertaking.

Tasks for the future include continuation of large-scale projects focussing on priority areas, development and maintenance of a database on bird casualties in order to refine priorities, international cooperation (conservationists as well as electricity suppliers) and securing of funding for the future (new EU budgetary period). For more details, see Schmidt (2011) and Antal (2010).

The choice between a cooperative approach and a more adversarial approach in any given country is partly determined by the number of electrical utility companies, and the position of the electrical utility companies (Antal, 2010). If too many utility companies exist, then it may be difficult for a coordinated, cooperative approach to function successfully. If sufficient information is available to demonstrate that mitigation is warranted, but the utility company is reluctant to act, then more use of a legal approach is justified.

3. Routing of new power lines

Line routing

Once it has been determined that an above ground power line is necessary, the best mitigation option is to ensure that it is routed away from areas that are home to, or attract, bird species that are known to be susceptible to electrocution or collision. Our understanding of the variables (and their interaction) influencing where electrocutions and collisions take place is certainly not complete. However, we do know that certain landscape and vegetation features are likely to be associated with higher rates of electrocution or collisions. In the case of electrocution, topography affects where birds will perch and roost, and vegetation height affects the availability of natural perches in the area. In the case of collision, topography affects whether birds will fly lower (*i.e.* down valleys) or higher (*i.e.* over mountains and hill slopes) as they optimise their energy efficiency in travelling. Vegetation height can also affect flight height, with short vegetation enabling lower flight. In addition to study area characteristics, it is important to take into account the protection status of the land. A number of options exist to collect information on protected sites, ranging from national, governmental or non-governmental websites on national parks, protected areas, Important Bird Areas (www.birdlife.org), Ramsar sites (www.ramsar.org), World Database on Protected Areas (www.wdpa.org) and many others. The most recent addition for the AEWA region is the

Critical Site Network (CSN) Tool as developed under the UNEP-GEF Wings Over Wetlands (WOW) African-Eurasian Flyways Project (www.wingsoverwetlands.org), which contains the information on Ramsar Sites, IBA's, SPA's and many other areas. **Appendix 1** presents an example of how information from aforementioned websites, together with information on the national power line network, can be combined to create a basic national 'potential conflict hotspot map'. The final decision on the routing of new power lines should at least also be based on all available ornithological knowledge.

Corridors and alternatives
In order to achieve the optimal routing it is useful if project planners identify more than one alternative route, as this allows for the selection of the optimal route with respect to bird factors. In addition, the use of a corridor (for example of two kilometres wide) for assessment rather than a single line provides an opportunity for small refinements to the route to be made within that corridor.

Grouping with other infrastructure
In certain cases, it may be possible to route a new power line adjacent to an existing taller power line with safe configuration, partially mitigating for electrocution through the likelihood that birds would naturally tend to perch on the taller power line and partially mitigating for collisions because birds will be more able to see the combined obstruction as well as have a greater likelihood of safely passing a second nearby line if this is of the same or lower height (Figure 1).

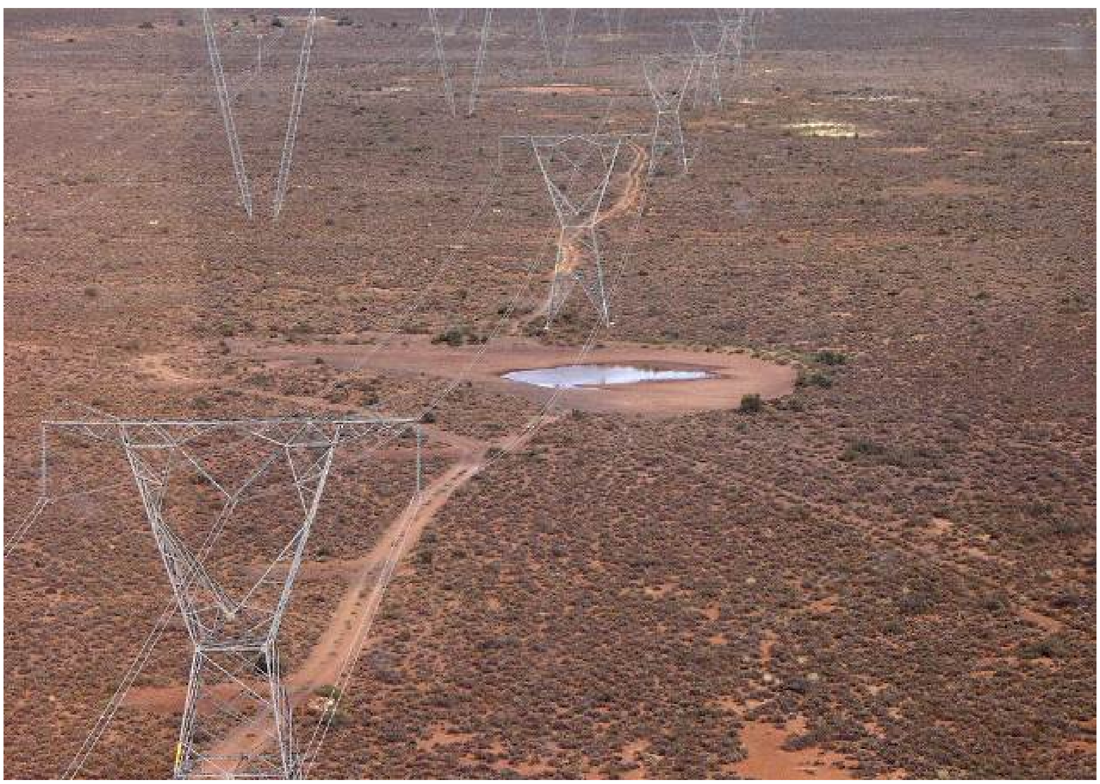


Figure 1. Two adjacent transmission lines in the Karoo region of South Africa. The sum of impacts on birds of two closely spaced lines may be importantly lower than when those lines were positioned far apart (Photo: EWT-WEP).

4. Decision-making: when and where to mitigate

When to mitigate

Determining when mitigation is required and the level of that mitigation is a key step in the overall management approach, and is dependent on the severity of the risk. Insufficient mitigation may allow an impact to escalate to the point of threatening a population, whilst unnecessary mitigation wastes resources, and undermines the credibility of the conservation approach. Risk is normally expressed in terms of biological risk, and mitigation is therefore normally implemented when a particular electrocution or collision impact is decided to be biologically significant. APLIC (1994) define bird mortalities as biologically significant "….when they affect a bird populations' ability to sustain itself or increase its numbers locally and throughout its range." However, mitigation can also be necessary in cases where social and political concern warrants it. Electrocutions and collisions may expose utilities to prosecution (where species are legally protected) and public relations risks, while electrocutions may also pose a risk of fire, damage equipment and impact on quality of the electricity supply.

Even with the best possible routing, as described in chapter 3, it is likely that sections of the route will still pose a risk to birds. These areas can be mitigated with 'on site' mitigation options, such as line modification and retrofitting, described in detail in the following chapter. It is important to note at this point that the implementation of most of the options is technically far easier, and far more cost effective if done at the construction stage, as potentially expensive power outs or specialised techniques will be less frequently needed. In addition, the cost of electrocution and collision mitigation measures can far more easily be accommodated in a construction budget (within which mitigation would make up a small component) than in the budget for maintenance once the line is commissioned. The precautionary principle should therefore be kept in mind when identifying mitigation needs. If in doubt, mitigate! Moreover, in many international conventions the 'precautionary principle' application is accepted and agreed as a formal obligation to be used in such situations.

Where to mitigate

Once power lines have been built and are operational, mitigation may (still) be implemented. This can be done either proactively, whereby the available information on previous fatalities and all related factors are used to predict where fatalities could occur in future (both for new and existing lines), or reactively, whereby action is taken in response to the occurrence of fatalities on existing lines.

For example, in Switzerland twelve priority regions were identified for Eurasian Eagle Owl (*Bubo bubo*) and White Stork (*Ciconia ciconia*) to assess the possibilities of technical rehabilitation of medium voltage power poles. In these regions, power poles will be checked in terms of safety for birds and dangerous poles will be made safe for use by birds (Heynen & Schmid, 2007). Similarly, in 2003 the Czech Republic was divided into three conflict zones based on the prevailing bird density and density of power lines (Schürenberg *et al.*, 2010). In Germany, the transmission network (110, 220 and 380 kV) of the transport system operator RWE was analysed in order to identify line segments with increased collision risks for birds. In this case, a rating system was developed that took into account the number of birds and species composition within functional areas, as well as the location and lay-out of the power lines in the landscape. The product of both measures was used to qualitatively assess the collision risk for every individual line section (area between two pylons). Using this system, the most problematic areas in the power line network of RWE could be identified (Bernshausen *et al.*, 2007). The line sections with increased collision risk added up to about 400 km of power lines (from ca. 10,000 km total). Between 2005 and 2008 these sections have been retrofitted with a new type of wire markers (see **Box 2**).

While these 'proactive risk assessments' studies are potentially very useful, and can make a significant contribution towards mitigating electrocution and collision, it is essential to ground truth the predictions before motivating to the utility company to spend money on the necessary mitigation. Clearly such a mitigation planning process requires good and comprehensive bird surveys and monitoring power lines for electrocuted and collided birds.
Reactive mitigation involves mitigating sections of line where birds have already collided or been electrocuted, with the view to reducing future impacts at those sites. Whilst this should be an important

component of any mitigation programme, it is not always adequate in the case of threatened bird species with already small populations, as it requires birds to die before any action is taken.

The following chapter presents a number of state-of-the-art techniques to mitigate or minimise impacts of power lines on birds.

5. Mitigating Electrocution and Collision Impact on Birds

5.1. Mitigating for electrocution

Electrocution mitigation can be far more controlled than collision mitigation. Since the problem is a physical one, whereby a bird bridges certain clearances on a pole structure, the solution is relatively straightforward, and involves ensuring that a bird cannot touch the relevant components. There is a large amount of literature available on how to avoid or mitigate for electrocution, examples from the African-Eurasian Flyways are reviewed in the AEWA/CMS International Review on Bird-Power Line Interactions (Prinsen *et al.*, 2011a). Extensive technical designs in a European context are presented in Haas & Nipkow (2003), Haas *et al.* (2005), and most recently, Haas & Schürenberg (2008). APLIC (2006) presents a large number of problem configurations from a North American context and give extensive technical guidance (including detailed technical drawings) for modification. Below the most important techniques are summarised and visualised by photos and drawings of the relevant key components.

Add on mitigation or retrofitting
An "avian-safe" power pole is a configuration designed to minimise bird electrocution risk by providing sufficient separation between energised phase conductors (also-called 'phases') and between phases and grounded hardware to accommodate at least the wrist-to-wrist or head-to-foot distance of a bird (Figure 2). If such separation (isolation) cannot be provided, exposed parts are covered (insulated) to reduce electrocution risk. It is possible to mitigate for electrocution on an already operational network, through retrofitting. The disadvantage of this approach is that it is costly, normally requires an outage (line switched off) with subsequent customer issues, and is essentially adding materials and complications to a previously approved engineering design.

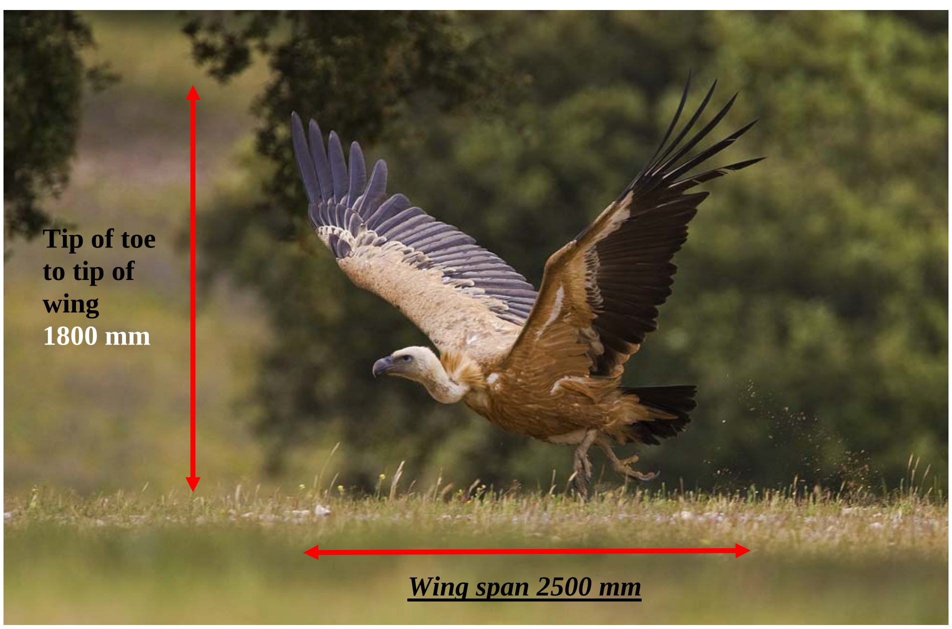


Figure 2. A Griffin Vulture (Gyps fulvus) with outstretched wings at take off. To mitigate for bird electrocution, distances between electric conductors (or phases) and distances between conductors and

grounded hardware should be separated over a larger distance than the wrist-to-wrist or head-to-foot distance of a bird. Because dry feathers provide insulation, the distance between fleshy parts, such as skin, feet or bill, is generally the critical factor to determine if a power line construction is safe for perching birds. Note, however, that wet bird feathers provide less insulation, therefore, in wet climates safe distances between energised parts should be based on wingspan and toe-to-wing tip distances of the largest perching protected species in the area (Photo: Bureau Waardenburg).

Retrofitting for avian-safe structures can include one or more of the following strategies (APLIC, 2006):

i) line design or configuration: increasing separations to achieve adequate separation for the species involved. When the power line is located within the distribution area of large raptors or storks, this distance should be increased to **1.4 m** (or even 1.8 m in the case of vultures, see below);

ii) insulation: covering energised parts and/or covering grounded parts with materials appropriate for providing incidental contact protection to birds. It is best to use suspended insulators and vertical disconnectors, if upright insulators or horizontal disconnectors are present, these should be covered. The length of insulated chains should be higher than **0.70 m**;

iii) applying perch management techniques.

<u>Line design or configuration</u>

This is relatively easily achieved through the technical design of the pole top. The design can take one or a combination of two approaches: either to ensure that the likely preferred perching space for a bird on the pole top is well clear of dangerous components; or to ensure that the dangerous components are sufficiently separated by space to ensure that the bird cannot touch them. This latter option, whilst more full proof, can result in significantly larger pole tops with consequent significantly increased costs, which is why a combination of the two approaches is often employed.

Line design modifications for mitigating bird casualties should include sufficient spacing between different conductors and between conductors and grounded wires or hardware. Short distances between conductors often occur at switch towers, at junctions and dead ends of distribution systems. In Europe, a minimum distance of 1.4 m between power lines is required and a space greater than 0.6 m between a likely perch site and the energised parts in order to reduce the risk of electrocution (Haas & Nipkow, 2006; Haas & Schürenberg, 2008). In countries with large perching raptors, such as large eagles and vultures, these distances should be greater (*i.e.* >2.7 m between power lines and >1.8 m between perches and energised parts in Africa). The table on the following page presents guidelines on requirements; these have been published before in a report published by the Bern Convention (Haas *et al.*, 2005) and were recently updated in Haas & Schürenberg (2008).

<u>Insulation</u>

Where poles or pylons or substation hardware pose a risk of electrocution to birds by virtue of the insufficient clearances between critical hardware (see previous paragraphs), it is possible to rectify the situation with add-on mitigation. This usually takes the form of insulating materials that are fitted onto critical components of the structure, in order to render those components neutral. In some cases this insulation takes the form of custom designed products for insulating certain components, and in other cases more universal, generic material is used, which can be adapted on site to insulate varying components. A feature of most of these products is that they often do not in fact provide full insulation, and should not be considered safe for humans. These materials often in fact only cover the dangerous components, reducing the likelihood of electrocution but not fully eliminating it.

Retrofitting (polymer) insulation may be carried out on ground wires, phase conductors (Figure 6), cross-arms (Figure 7) and jumper wires (Figure 8), both at tap and dead end locations, especially where bare energised wires connect transformers. By insulating the wires altogether, the insulators will no longer be required, and the wires can be directly attached to the poles (Figure 9). However, attaching the power lines to large suspended insulators below the cross-arms (hanging insulators) instead of to upright insulators already helps to reduce the problem (Figure 4). It is also important that insulators are not attached to cross-arms with metal pins or similar conductive material because this can result in a circuit grounding through the bird should it perch on such an insulator. The replacement of steel on power poles is also suggested to be an effective mitigation measure, especially of cross-arm braces.

Pole structure type	**Minimum conductor-conductor clearance**	**Minimum conductor-ground clearance**	**Add on mitigation/comment**
Terminal structures (transformers) (Figure 3)	-	-	All terminal structures should be constructed with sufficient insulation on jumper wires and surge arrestors
Strain structures (where jumpers are used) (Figure 8)	-	-	At least two jumper wires should be suspended below the cross-arm, and the third jumper insulated. Alternatively all jumpers should be insulated (Figure 8)
Take-off structures	-	-	All jumpers should be insulated (Figures 3 and 8)
Switches/isolators	-	-	Switches should be designed so that perching by birds on switch gear is unlikely, and/or all dangerous components are insulated. Switch gear should preferably be mounted below the cross-arm. Alternatively, insulated perch sites are installed way above the switch gear over the whole length (Figure 5)
Intermediate structures with horizontal configuration of lines (Figure 4)	Large enough to accommodate the wingspan (or ‘wrist-to-wrist’) of the largest perching bird species in the country if all three phases are above the cross-arm. Alternatively two outer conductors should be suspended below cross-arm. For example 2,700 mm in South Africa, based on large vultures.	Same as conductor-conductor clearance	If three conductors are positioned above cross-arm, centre conductor can be insulated in order to achieve necessary clearance between two outer conductors (Figure 13)
Intermediate structures with vertical or ‘delta’ configuration of lines	Large enough to accommodate the ‘tip-of-toe to tip-of-beak or outstretched wing’ or ‘head-to-foot’ dimension (Figure 2) of largest species present. For example 1,800 mm in South Africa, based on large vultures.	Same as conductor-conductor clearance	On staggered vertical structures of 66 kV to 132 kV add on mitigation in the form of ‘Bird Perch’ and diagonal bar to prevent perching on cross-arms could also be applied, but see text on ‘perch management techniques’

Figure 3. Left: Distribution substation with some closely spaced energised parts that is potentially dangerous to birds. Retrofitting could include insulation of vertical hanging wires and spatial separation of energised parts. Right: End pole of distribution line; jumper wires (arrow) are constructed below conductors and insulators are more than 60 cm long, providing a bird-safe perch on top of the pole (Photos: Bureau Waardenburg).

Figure 4. Left: a safe horizontal low voltage line, with three conductors suspended below cross-arm with sufficiently long insulators. Right: a low voltage line in Iceland unsafe for larger waders, here Whimbrel (Numenius phaeopus) and Black-tailed Godwit (Limosa limosa islandica) and larger raptors (in this case White-tailed Eagle (Haliaeetus albicilla) and Gyr Falcon (Falco rusticolus)) because of conductors attached on short insulators on top of cross-arm. In this case retrofitting could include insulating the central conductor wire and/or covering the insulators (Photo: Bureau Waardenburg).

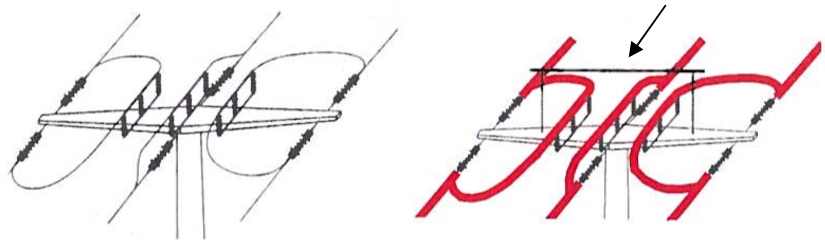


Figure 5. Left: Medium voltage pole with switch gear dangerous to perching birds because of short distances between energised parts. Right: Same pole after insulation of all energised wires close to the cross-arm (in red) and installing insulated safe perch (see arrow) (source: Haas et al.*, 2008).*

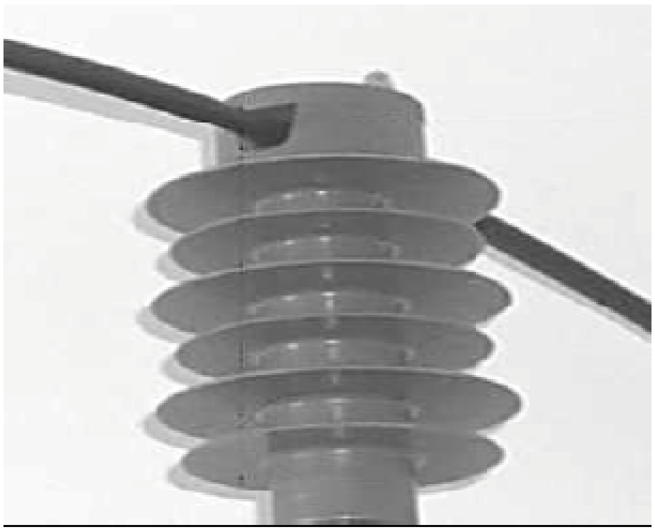


Figure 6. Example of an insulated conductor wire (black wire) used in Hungary (source: Podonyi, 2011).

Figure 7. Cross-arm insulation carried out in Hungary (source: Horvath et al., 2011).

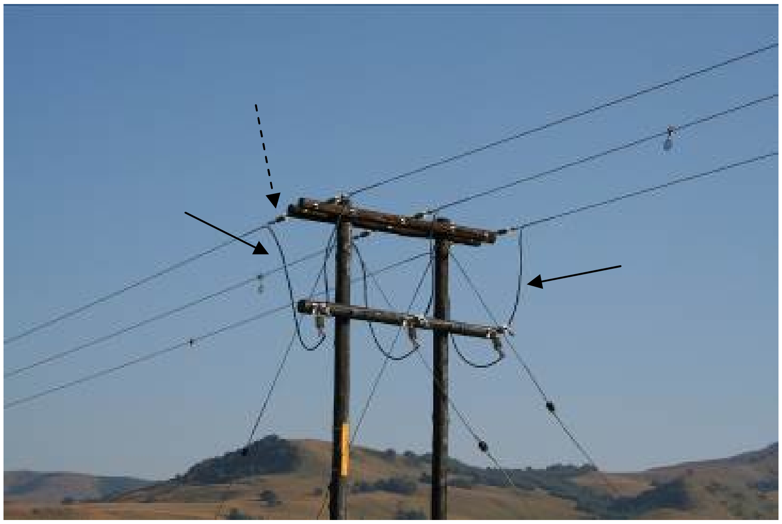


Figure 8. A safe strain pole structure, with insulated jumper wires (black arrows) and sufficiently long insulators (broken arrow) (Photo: EWT-WEP).

Figure 9. Completely insulated medium tension cable in Spain hanging from concrete pole without need of insulators (source: Haas, 2011).

The electrocution of raptors and collisions of waterfowl have been drastically reduced in Doñana National Park since 1988, when aerial insulated cables forming a single bundle (Figure 9) replaced the most dangerous lines. The operation, involving 33 km of lines, costed approximately 1.5 million US$. This effort has proven to be the most successful management strategy to safeguard the Spanish Imperial Eagle in the Park (Negro & Ferrer, 1995 and references therein).

Perch management techniques

Cross-arms, insulators and other parts of the power lines can be constructed so that there is no space for birds to perch where they can be proximate to energised wires. This happens often by exclusion devices, or perch discouragers (Figures 10 and 11), but often these cause even more problems than benefits. Because the birds still try to perch on the constructions and the space is even more limited, birds have a higher chance to contact the energised wires. For example, in Mongolia, 45% of the poles along a 140 kilometre section of power line had steel cross-arms fitted with one to four 38 cm bird spikes to discourage perching. However, despite the presence of these spikes, 50% of all raptor carcasses were found under these poles, and hence there was no significant difference in mortality between poles with and without perch discouragers (Harness *et al.*, 2008). On the other hand, there has been considerable success achieved by providing artificial bird safe perches (Figures 12 and 13) and nesting platforms (Figures 14 and 15), which are placed at a safe distance from the energised parts (Bayle, 1999; Goudie, 2006).

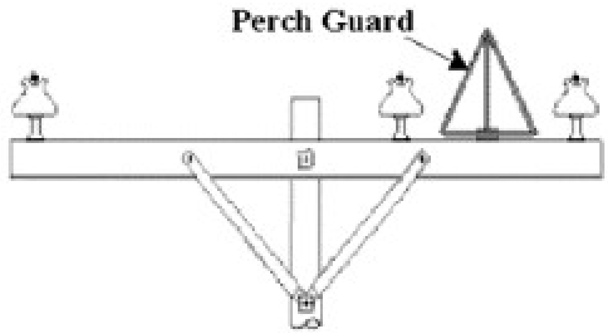


Figure 10. Distribution pole with perch guard as exclusion device (source: Hunting, 2002).

Figure 11. Distribution pole with symmetric chevron (arrow) on top as bird exclusion device (Photo: EDP-Distribution, Portugal; and distribution pole with bird exclusion spikes with dedicated nesting pole for White Stork next to it (Photo: Carlos Tiago).

Figure 12. A Pale Chanting Goshawk (Melierax canorus) perched safely on a 'Bird Perch' (Photo: EWT-WEP).

Figure 13. A 'Raptor Protector' used to insulate the centre conductor of a 22 kV pole structure making the distances between non-insulated conductors large enough for safe perching (Photo: EWT-WEP).

Figure 14. Example of perching device for storks in Algeria (left picture taken from returned questionnaire Algeria; S. Hamida, Head of Wetlands Office, General Direction of Forests, Algeria, in litt.) and example from Portugal of pole with nesting platform for White Stork dedicated to attract storks and prevent them from nesting in power line masts (right picture photo by Carlos Tiago).

Figure 15. Nesting Osprey on artificial platform in medium voltage transmission line, Muritz National Park, Germany (Photo; Bureau Waardenburg).

Deterring birds from power lines
Visual deterrents have been trialled in the past (such as the use of raptor silhouettes placed on pylons as deterrents to reduce bird flights over lines, Janss *et al.*, 1999) but have proven to be ineffective. These devices almost certainly suffer from bird habituation. Audio or acoustic deterrents have potential, although no literature on their effectiveness is available. It is anticipated that habituation could be a challenge with this approach. All these techniques cannot be applied over long distances other than at high costs and they will over time lose their effect. Permanent solutions (line design or isolation and insulation) as illustrated above are much better and much more cost effective.

Habitat modification
Habitat modification can be used in various ways, including: shielding of the line by trees; altering the attractiveness of the habitat close to the line; and changing the disturbance levels close to the line. However, with all of these options there are often challenges of spatial scale. Habitat modification would therefore need to be implemented on a large scale in order to manipulate bird movement successfully. Also in some cases, long sections of line may pose a risk, thereby requiring a significant level of habitat modification, not to mention environmental and financial costs.

5.2. Mitigating for collision

Once infrastructure exists, line modification in various forms is the other known approach, and is the most widely used (APLIC, 1994; Hunting, 2002; Crowder & Rhodes, 2001; Drewitt & Langston, 2008). Line modification can take several forms, which can be broadly divided into those measures that make power lines present less of an ‘obstacle’ for birds to collide with, those that keep birds away from the power line (see above under ‘deterring birds from power lines and habitat modification’) and those that make the power line more visible.

Line design or configuration – presenting less of an ‘obstacle’ to flying birds
Although different bird species fly at different heights above the ground, there is general consensus that the lower power line cables are to the ground, the better for preventing bird collision. There is also consensus that less vertical separation of cables is preferred as it poses less of an ‘obstacle’ for birds to collide with. Horizontal separation of conductors is therefore preferred (Figures 16, 17 and 18). Since bird collisions have been recorded with the guy or stay wires of towers, the construction of self-supporting towers, which do not require stay wires, is preferred. Birds are believed to collide most often with the earth or shield wire (the thinnest wire at the top of the power line structure, Figure 16). Removing this wire or designing power lines from the outset without this wire is therefore a potential collision mitigation measure (Brown *et al.*, 1987; Bevanger & Brøseth, 2001). This has been shown to be effective in

protecting birds as varied in size and biology as cranes (*Gruidae*) and ptarmigan (*Tetraonidae*) (in Jenkins *et al*., 2010). However, since these wires are used to protect the infrastructure from lightning, this is unlikely to be a widely used measure unless a viable alternative for lightning protection is developed.

Figure 16. A 400 kV line, with all conductor wires in the same horizontal plane. This picture also demonstrates the almost invisible thin earth wire (black arrow) in top (Photo: EWT-WEP).

Figure 17. A 380 kV line, with lowered conductor wires hanging from portals in one horizontal plane to minimise collision risk for Great Cormorant (Phalacrocorax carbo), Eurasian Spoonbill (Platalea leucorodia) and Purple Heron (Ardea purpurea) daily passing this stretch of line while commuting between the breeding colony and foraging areas, Muiden, the Netherlands (Photo: Bureau Waardenburg).

Figure 18. A vertical cable configuration, with cables at four levels (three phase conductors and a ground wire). Compare to the figures above where the horizontal configuration results in cables at only two levels. Multilevel vertical arrangements are more dangerous to birds because they provide an obstacle over a greater plane (Photo: EWT-WEP).

Line marking – making lines more visible to birds

i. Line marking devices

Since the assumption is that birds collide with overhead cables because they cannot see them, fitting the cables with devices in order to make them more visible to birds in flight has become the preferred mitigation option worldwide. Besides thickening, coating or colouring the often least visible thin ground wires, a wide range of potential 'line marking' devices has evolved over the years, including: spheres, swinging plates, spiral vibration dampers, strips, swan flight diverters, Firefly Bird Flight Diverters, bird flappers, aerial marker spheres, ribbons, tapes, flags, fishing floats, aviation balls and crossed bands (Figures 19-21). There is a large amount of literature available on efficiency of such marking devices in mitigating collision mortality, some examples from the African-Eurasian Flyways region are presented in the AEWA/CMS International Review on Bird-Power Line Interactions (Prinsen *et al.*, 2011a). Although there is generally a lack of quality evaluative research of the effectiveness of these devices at the international level, the evidence to date suggests generally positive results (Jenkins et al, 2010; Barrientos *et al.*, 2011). Jenkins *et al.* (2010) conclude that, barring some notable exceptions, "any sufficiently large form of marker (which thickens the appearance of the line at that point by at least 20 cm, over a length of at least 10-20 cm), placed with sufficient regularity (at least every 5-10 m) on either the ground wires (preferably) or the conductors, is likely to lower general collision rates by 50-80%". Barrientos *et al.* (2011), reviewing 21 wire marking studies, similarly conclude that wire marking reduced bird mortality by 55-94%. Further, comparisons of two different marking devices under the same conditions (Janss & Ferrer, 1998; Brown & Drewien, 1995; Crowder, 2000; Anderson, 2002), revealed that only thin plastic strips (Janss & Ferrer, 1998) were not as effective as the alternatives. Beyond this, the differences in effectiveness between widely ranging devices was negligible.

Figure 19. Medium voltage distribution line with small spirals (so-called 'pig tails') placed at regular intervals in the conductors as bird flight diverters (Photo: Bureau Waardenburg).

Figure 20. High tension (150 kV) power line in the Netherlands with bird flappers (see arrows) placed at regular intervals in both ground wires as bird flight diverters, see also Box 1 (Photo: Bureau Waardenburg).

Figure 21. Various line marking devices (not comprehensive). In each photo a pen (circa 14 cm length) is placed to provide scale (Photo: EWT-WEP).

Several improvements in devices recently include the emphasis of appropriate colouration to maximise effect within the avian visual spectrum (Crowder & Rhodes, 2001), and increased support for dynamic (devices with moving parts) 'flapper' devices rather than static devices (in Jenkins *et al*., 2010). These improvements may have merit, but are yet to be supported by much scientific evidence (see also **Box 2**). Furthermore, there is consensus that nocturnal collisions are important in various species (*e.g.* Brown & Drewien, 1995; Hunting, 2002). Several potential nocturnal devices, some with illuminating parts (*e.g.*, FireFly diverters), have been developed but, at present, their effectiveness is poorly known (see also Box 2).

There is room for improvement in the efficacy of line marking devices. In order to achieve this improvement we need to look more closely at bird vision. Recently, Martin & Shaw (2010) and Martin (2011) conducted the first known research into avian visual fields related to power line collision. Key research findings and theoretical conclusions include:

- birds' vision differs from humans in three main ways: colour vision, acuity and field of view;
- birds' eyes are mostly placed laterally in the skull, birds' visual fields (*i.e.* where they can see) are extensive, and differ between species;
- relative to humans, birds have small blind spots. However, these blind spots can render a bird blind in the direction of travel, if the head or eye is moved in a certain way;
- birds have small binocular fields, particularly the cranes and bustards. Binocular vision is important for distance perception;
- birds' highest visual acuity and colour vision is in their lateral visual field, birds' frontal vision may be tuned for detecting movement rather than spatial detail;
- birds in flight in open habitats may 'predict' that there are no obstacles in front of them;
- birds may detect obstacles such as pylons, and fly towards them with the intention of veering away at the last minute (direction and time to contact measurements are derived from this behaviour) only to collide with the undetected cables.

Based on the above findings, future development of devices should consider the following:

- line markers should be as large as possible, and increase the visible thickness of the line by at least 20 cm, for a length of at least 10-20cm;
- spacing of devices should be not more than 5-10 m apart;
- line markers should incorporate as much contrast with relevant backgrounds as possible;
- colour is probably less important than contrast;
- movement of the device is likely to be important;
- markers that protrude vertically both above and below the cable are likely important;
- since we suspect that many collisions may occur at night, devices that are nocturnally visible (through illumination, phosphorescence, ultraviolet radiation and other means) would be advantageous. Although bearing in mind what is known about birds being attracted to illuminated objects.

ii. Device technical features

The aim with any marking device should be for it to last as long as the line itself, only requiring replacement once the line is refurbished or rebuilt. However, experience to date has shown that this is seldom if ever achieved. In order to ensure durability of devices as far as possible the following should be considered before installing new devices:

- steel components should be stainless steel;
- plastic components should be ultraviolet (UV) radiation stable high impacted PVC;
- connections between parts (particularly plastic on steel) must be re-enforced with stainless steel grommets;
- the device clamping mechanism must not allow any movement at all once installed on the conductor;
- the device may not damage the conductor onto which it is placed;
- the device may not cause corona;
- with devices which make use of a flapper attached to a clamp, the flapper sections must not be able to flip up over the clamp and conductor;
- connector part mechanisms must be burr free;
- the device must be removable.

As far as possible these aspects should be extensively tested in a laboratory/simulated environment prior to installation.

iii. Device installation

Devices should be installed on the earth wire (also-called ground or shield wire) wherever possible. On lines without an earth wire devices should be installed on the conductors. Although installation of these devices on higher voltage conductors is problematic, lines of higher voltage would typically have an earth wire anyway. As described above, line marking devices should be installed at 5-10 m intervals on the earth wire where present, or on the conductors where no earth wire is present. Research has shown that it may be adequate to install devices on the central 60% of the span. For example, Shaw *et al.* (2010) found that most collisions occurred on the central three fifths of the span. Faanes (1987), Hoerschelmann *et al.* (1988) and Anderson (2002) had similar findings previously. Those authors postulated that this was due to the cables closer to pylons and towers being more visible. However, given that in many cases a large proportion of the cost of installation lies in getting the team and equipment to site, it is probably worth rather marking the full line whilst there, particularly with smaller lines <132 kV. It is our recommendation that 100% of the span is marked on all lines of 132 kV and below, and that partial marking only be considered on lines of higher voltage.

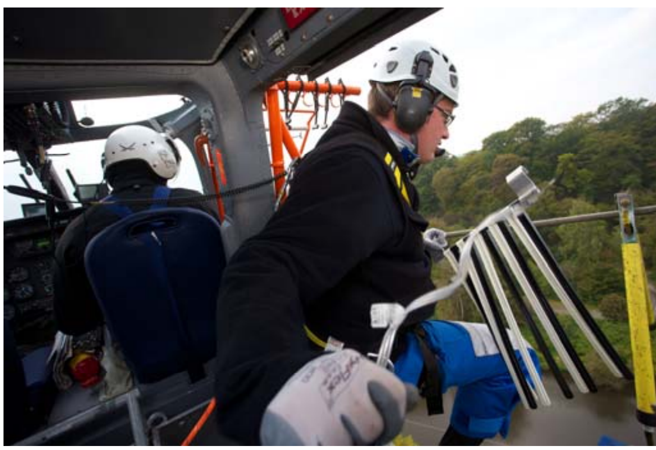
BOX 2. Recent developments in Bird Flight Diverters

Based on the information presented in this chapter two new types of Bird Flight Diverters (BFDs) deserve special attention, because they are largely in accordance with the technical features mentioned for successful collision mitigation: the bird flappers used by RWE Rhein-Ruhr Netzservice from Germany and the FireFly BFDs developed by AB Hammarprodukter from Sweden.

Bird Flappers

Between 2002 and 2005 RWE constructed and extensively laboratory tested new marking devices consisting of 50 cm long hard plastic black and white strips constructed on an aluminium clamp (Figure 20). Since summer 2005 more than 13,000 of these so-called ‘bird flappers’ have been installed on earth wires of high tension power lines in Germany, using a specially retooled helicopter to guarantee rapid installation advancement without impairment of the power supply. Bernshausen & Kreuziger (2009) demonstrated a collision reduction of more than 90% for gulls at a power line section near a large gull roost that had been retrofitted with bird these bird flappers. More recently, in a study in the Netherlands, Hartman *et al*. (2010) found a significant reduction of 80% in the nocturnal collisions of ducks (Mallard (Anas platyrhynchos) and Wigeon (Anas penelope)) on a four kilometre long stretch of 150 kV power line through bird-rich grassland polders fitted with these bird flappers (Figure 20). However, for Coot (Fulica atra), for which many tens of collision victims were found and were also believed to have collided at night, the reduction in collision victims was negligible. For species that collided during the day (e.g., gulls, waders, pigeons) the statistically significant reduction amounted to 67%, but the number of victims per species was too low to calculate species-specific reductions (see also Prinsen *et al*., 2011b).

The German bird flappers are large and contrast-rich and the strips move individually in the wind resulting in a blinking effect that likely makes them well visible for approaching birds in twilight or even darkness. Because of their weight it is not possible to install a large number at one single span of an earth wire, distances between individual flappers are typically several tens of meters.



For more technical information: www.rwerheinruhrnetzservice.com

FireFly BFDs

The FireFly consists of a rotating hard plastic disc or rectangular plate with fluorescent parts (e.g. top left and top right pictures in Figure 21). These devices reflect sunlight during the daylight hours and emit luminescent light during twilight and at night. This sparkling and refraction of light allows the birds to change their flight pattern to divert around the marked wires and avoid collisions. The rotational speed of the Firefly increases its effectiveness, although so far few results have been published. Yee (2007) found a 60% reduction in the number of fatalities of Sandhill Crane (*Grus canadensis*) under a treated 12 kV distribution line and Murphy *et al*. (2009) reported up to 67% reduction in the number of fatalities of the same species under two treated 69 kV transmission lines. Because of its relatively small size and light weight distances between individual FireFly BDFs can be small, often within the quoted 5-10 m distance. For more technical information: www.hammarprodukter.com

6. Impact monitoring and evaluation of mitigation effectiveness

Identifying an electrocution or collision impact

Many bird electrocution and collision problems are initially identified through the detection of carcasses under a power line by utility staff, landowners, the public, researchers, conservationists or birders. In most cases this is not the result of systematic line searching, but rather chance detection. Fortunately, most electrocution victims fall close to the base of the pole, and not mid-span as is the case with collisions. This increases the chances of detection since access to poles is normally better and maintenance staff typically visits poles more frequently. Another reason why electrocution victims have a greater chance of being detected than collision victims is that electrocution often results in a power dip or outage, as it is essentially a short circuit. This dip or outage would be registered on the utilities system and in many cases would prompt a field investigation by utility staff. However, as with collisions, numerous biases still affect these data, including, amongst others, the proximity of the power line to a road, vegetation type, size of bird, bird colouration and topography.

The next step in the process, the person actually reporting the electrocution mortality to the correct authority, is again plagued by bias. For example, a threatened species is far more likely to be reported than a common species, and species for which there is an existing affinity, such as storks, are more likely to be reported than vultures perhaps (which suffer from a bad reputation). It is not surprising then that many datasets have been biased towards larger, more prominent, charismatic or threatened species. Whilst these data can be a useful indicator of a potential problem of electrocution or collision, it should not be too heavily relied upon in assessing the extent or significance of the problem.

Wherever possible, more systematic line searches and regular line monitoring should be implemented in order to produce more rigorous data that can facilitate confident decision-making (see **Box 3**).

Evaluation of the effectiveness of mitigation

The evaluation of mitigation is an essential, but often overlooked, component of the approach to reduce bird electrocutions and collisions (*e.g.*, APLIC, 2006; Barov, 2011; Barrientos *et al.*, 2011). Typically, the measurement of the effectiveness of any mitigation measure is carried out through systematic monitoring of the section of line concerned. This involves driving or walking along the power line and searching for collision victims (bird carcasses). These data are subject to several biases such as detection bias (the percentage of dead birds that are actually found, which varies with habitat and topography), the scavenger removal bias (the percentage of birds that collide, that remain after a certain time period, not removed by scavengers), and the crippling bias (those birds that are injured but manage to move away from the power line sufficiently to avoid detection). Experiments and tests may provide complimentary information that allow these biases to be estimated in order to improve confidence levels in the final estimates of collision rates (see **Box 3**). One of the challenges of this type of work is the sheer volume of time taken by field observers, particularly if line patrols are done reasonably frequently. A means to overcome this is the use of remote data collection, through devices such as the Bird Strike Indicator (Arun *et al.*, 2008; Murphy *et al.*, 2009), which records bird collisions through sensing vibrations along the cable (Figure 22).

It is highly recommended that evaluation and monitoring programmes, study designs and protocols are internationally standardised to overcome the large differences in the methodologies currently in use. Several reviews (APLIC, 2006; Jenkins *et al.*, 2010; Barrientos *et al.*, 2011) conclude that experimental rigour (in terms of spatial and temporal effort) and standards are insufficient to render statistically and scientific sound data, which can be used, for example, to compare mitigation measures between species and areas or establish the impact of power lines on bird populations at the regional or wider scale.

BOX 3: More systematic line searches and monitoring

Below we present some suggestions for more standardised and systematic approaches to line searches and monitoring. Because factors that affect the search efficiency, scavenger rate, accessibility of terrain, *etc*., vary greatly between study locations, it is not possible to present a method that is applicable in all situations and study outlines may need to be developed on a case-by-case basis. Nevertheless, the following topics are of importance to consider and incorporate in such a study protocol in order to make studies more comparable.

Spatial and temporal coverage

Line searches for power line victims (both for identifying impacts as well as evaluation of mitigation measures) should be sufficiently extensive, both spatial and temporal. Most collision victims are found within 50 metres distance from a power line but, if feasible, larger distances from the line should be incorporated in the search protocol in order to ensure that those victims that have fallen to the ground further away are included. The search area should, therefore, include the area up to at least 40-50 metres, on both sides, measured from the centre of the line. Depending on the size of the victims (small passerines to large swans), the type of terrain (irregular surface, hollows, rocks, etc.), and vegetation cover (size and structure), the search intensity needs to be adjusted. An observer should be able to find medium sized birds (*e.g*., ducks) in flat terrain with low vegetation within a radius of 10 metres around him. Preferably, the terrain is covered on foot, but for large open bare areas, searches can be carried out by car. Because most electrocution victims fall close to the base of the pole, in case of electrocution monitoring a search radius of 10 metres around poles and pylons will suffice.

Victim searches should be carried out often enough to prevent too many victims being lost to scavengers. The smaller the bird victims are, the more often searches have to be carried out. For most waterbirds (small to medium sized) and birds of prey, an intensity of twice weekly or once a week is sufficient. When only large conspicuous birds (swans, storks, eagles, cranes, bustards) are searched for fortnightly searches may be sufficient.

Blue Crane (Anthropoides paradisea), collision victim of transmission line in South Africa found during a dedicated search of collision victims of this species. Approximately 12% of the total Blue Crane population within the Overberg study area at the Western Cape could be killed annually in power line collisions (Photo: EWT-WEP).

What to note when finding a carcass

Of course it is necessary to establish which species is involved. Often this may be difficult when few parts of the carcass remain. There are, however, several web sites and books detailing the identification of birds by its individual feathers. The position of the carcass should be printed on a map or form to later identify the most problematic line sections or poles. It can also give information with which line (conductors or ground wires) the bird has collided. Information on age and sex of the bird should be noted to analyse the effect of age and gender on susceptibility for electrocution and collision. Finally, it is important to establish if the dead bird has truly suffered from an impact with the power line or if there is another reason how the bird died.

Cause of death

If possible, determine the cause of death by autopsy to exclude other unnatural death causes than electrocution or collision such as shooting or kills by birds of prey. Evidence of electrocution can include burn marks on feathers, feet, or bill, visible as *e.g*., small well-defined burn holes in the plumage, scorched areas at current entry and exit points, or large necrotic areas on the limbs. Evidence of collision can include fractured bones of the extremities (wings, legs and shoulder bones), broken vertebrae and skull fractures, torn off wings and limbs, flesh wounds, impact wounds on head or body where the bird hit the wire. Birds that have been shot often show shattered bones, spattered blood, contusions and bullet wounds (references in APLIC, 2006; Haas *et al*., 2005).

Searcher detection & scavenger removal experiments

Dedicated line searches and evaluation of mitigation measures should include experiments to correct for searcher detection bias and scavenger removal bias. Rates to correct for both biases should be established with experiments in which carcasses are laid out below and near the studied power line sections.

In searcher detection experiments searchers are not aware that colleague researchers have put out ‘test’ carcasses. Trial administrators should therefore be careful not to put out too many carcasses at once or leave traces, such as footprints or tags on trial carcasses, otherwise they may influence search intensity. Preferably ‘test’ carcasses are similar in size and colour of the species normally encountered in the impact study. In cases where a broad range of electrocution or collision victims are involved, the test carcasses should be of various sizes (small, medium and large birds) and colours. Use of chicken or feral pigeon carcasses as surrogates is discouraged as these are often more rapidly removed by scavengers than species that are typically found as electrocution or collision victim. They will also notify the searchers of the ongoing experiment.

The duration and season of the tests is of importance as well as intervals between carcass searches. For example, especially in northern latitudes, some vertebrate scavengers might be more inclined to remove carcasses during autumn to build body fat for winter (Smallwood, 2007). It is also important not to put out too many carcasses at once, because this may give scavengers more than they can remove and process and carcasses may become unattractive as food because of rotting or mummification processes. This again may strongly bias mortality estimates. Smallwood (2007) describes further potential sources of error and bias in this kind of experiments, such as use of frozen carcasses and whole instead of dismembered carcasses, as well as details the calculation of correction factors.

The monitoring of live bird movement is even less commonly conducted than the dead bird searches. Without estimates of how many birds actually crossed the line in flight, the collision rates calculated through dead bird searches are less meaningful. Direct observation of live bird movement is extremely time consuming. Remote techniques such as radar, however, can be used in order to obtain data with less human resources needed (*e.g.*, Gyimesi *et al.*, 2010; Hartman *et al.*, 2010; Krijgsveld *et al.*, 2010; Prinsen *et al*. 2011b), although observations to ground truth the radar data are required. In some countries the assistance of volunteers of bird conservation and research organisations is a welcome source of manpower, but in the majority of countries within the African-Eurasian region this source of manpower and expertise is simply not available.

Figure 22. Bird Strike Indicator (BSI) attached to a power line. BSIs are relatively small devices that can be attached to a single wire of a power line and automatically register bird collisions based on the vibration of the wire.

7. Recommended sources of information and guidance

As noted in the introduction, guidelines on the conflict between birds and power lines have been published before. Below, a list is provided, as a 'guide to guidance', of the most important other sources of information and guidelines relevant to the issue of bird and power lines interactions. For a more complete overview of published and non-published references on this topic we refer to the accompanying AEWA/CMS International Review on Bird-Power Line Interactions (Prinsen *et al*., 2011) and selected references in the back of the guidelines report at hand.

Strategic planning, legislation and organisational approach

Detailed information on the SEA and EIA process and its benefits for birds can be obtained in the AEWA Conservation Guidelines No. 11, 'Guidelines on how to avoid minimise or mitigate the impact of infrastructure developments and related disturbance affecting birds' (Tucker & Treweek, 2008). That AEWA guideline report also contains an extensive list of recommended sources of information and guidance on SEA and EIA in its appendix D.

Mitigating electrocution and collision impact

Avian Powerline Interaction Committee (United States)
APLIC 1994, 'Mitigating Bird Collisions with Power Lines' document to be updated in a new publication foreseen for end 2011
APLIC 2006, 'Suggested Practices for Avian Protection on Power Lines' document detailing state-of-the-art in electrocution mitigation from a North American perspective
Avian Protection Plan (APP) Guidelines
For more information and ordering reports: www.aplic.org

International Conference on Power Lines and Bird Mortality in Europe, Budapest, Hungary, April 2011
Posters and presentations can be downloaded from: http://www.mme.hu/termeszetvedelem/budapest-conference-13-04-2011/presentations.html

BirdLife Germany (NABU) Working Group on Electrocution:
The website of the working group: www.birdsandpowerlines.org
General website of NABU presenting information on electrocution and links to several important papers and documents, including background documents to Recommendation No. 110 on minimising adverse effects of above ground power lines adopted by the Bern Convention Standing Committee in 2004 and NABU Guidelines on electrocution in several languages:
http://www.nabu.de/tiereundpflanzen/voegel/forschung/stromtod/05166.html

Information on Bird Flappers Bird Flight Diverters:
www.rwerheinruhrnetzservice.com

Information on FireFly Bird Flight Diverters:
www.hammarprodukter.com

Bird Survey and monitoring techniques
Specific power line search and monitoring protocols are not readily available and will probably contain site-specific guidance (see **Box 3**). The following references may be helpful when setting up a more general monitoring scheme and protocol and may be of help to prepare site inventories of birds.

AEWA Guidelines
- AEWA Conservation Guidelines No. 9, 'Guidelines for a waterbird monitoring protocol'
- AEWA Conservation Guidelines No. 3, 'Guidelines on the preparation of site inventories for migratory waterbirds'
- AEWA Conservation Guidelines No. 11, 'Guidelines on how to avoid minimise or mitigate the impact of infrastructure developments and related disturbance affecting birds' lists useful publications on the subject.

All three can be downloaded from http://www.unep-aewa.org/publications/technical_series.htm

Wetlands International
Guidelines for participants in the International Waterbird Census (IWC):
http://www.wetlands.org/LinkClick.aspx?fileticket=OD3kxbpZ1Kw%3D&tabid=56
(or Google "Wetlands International information for waterbird counters")

Waterbird flyway and site data
"Wings Over Wetlands" Critical Site Network (CSN) Tool: www.wingsoverwetlands.org/csntool
This website provides species and site data on most waterbirds in the AEWA region. It includes also the information on Ramsar sites, Important Bird Areas, and Natura 2000 SPAs, listed below.

Ramsar Convention on Wetlands: www.ramsar.org
For a worldwide overview of the Ramsar sites: http://ramsar.wetlands.org/

BirdLife International's Important Bird Area data: http://www.birdlife.org/datazone/home

Natura 2000 Special Protection Areas in Europe: http://natura2000.eea.europa.eu/

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Glossary

(for the descriptions in this glossary we used the glossary in APLIC (2006) and internet sources)

Avian-safe
A power pole configuration designed to minimise avian electrocution risk by providing a separation between energised conductors or phases and grounded hardware larger than the wrist-to-wrist or head-to-foot distance of a bird. If such separation cannot be provided, exposed bare parts are covered to reduce electrocution risk, or perch management is employed.

Bushing (transformer)
An insulator, usually made of porcelain, inserted in the top of a transformer to isolate the electrical leads of the transformer. To prevent dangerous contact by birds, bushing can be covered.

Conductor
The material (usually copper or aluminium), mostly in the form of a wire or cable, suitable for carrying an electric current.

Configuration
The arrangement of parts or equipment, for example, a distribution configuration would include the necessary arrangement of cross-arms, braces, insulators, etc. to support one or more conductors.

Corvid
Birds belonging to the family Corvidae; including crows, ravens, magpies, and jays.

Cross-arm
A horizontal supporting part of a pole or pylon; made of wood, concrete, or steel, manufactured in various lengths, and used to support electrical conductors and equipment for the purpose of distributing electrical energy.

De-energised
Any electrical conducting device disconnected from all sources of electricity.

Distribution line
A circuit of medium voltage wires, energised at voltages from ~1 kV to 60 kV, and used to distribute electricity to residential, industrial and commercial customers.

Earth wire
See ground wire.

Energised
Any electrical conducting device connected to any source of electricity.

Fault
A power disturbance, for example caused by animal electrocution, that interrupts the quality of electrical supply.

Ground wire, grounded parts
A wire (or parts) that makes an electrical connection with the earth and therefore is at ground potential.

High voltage power lines
High voltage power lines (60 kV up to 700 kV) are generally used for transmission networks. Because high voltage power lines mostly have long suspended insulators the electrocution risk for birds is relatively low. On the other hand, collision risk can be high, particularly where phase conductors and ground wires are arranged at different heights. The ground wire is often relatively thin and presents a particularly high collision risk.

Insulator
Non-conductive material, usually made of porcelain or polymer, in a form designed to support a energised conductor physically and to separate it electrically from another conductor or object.

Jumper wire
An energised conductive wire used to connect various types of electrical equipment. Jumper wires are also used to make electrical conductors on lines continuous when it becomes necessary to change direction of the line (*e.g.*, angle poles, dead-end poles).

Kilovolt or kV
1,000 volts

Low voltage power lines
Power lines are categorised, in part, by the voltage levels to which they are energised. Different authors often use different categorisation. Throughout the report we use the definitions by Haas *et al.* (2005) and APLIC (2006): low voltage or utility lines have a voltage 100 times less than medium voltage lines (*i.e.*, <600 volts). In most countries these are routed underground and therefore offer no risk to bird populations. Where these lines occur above ground, they tend to be relatively well insulated. Low voltage power lines are often thick, darkly coloured and relatively visible, therefore posing a relatively low collision risk.

Medium voltage power lines
These include distribution power lines of utility companies (~1 kV to 60 kV). While in some countries the majority of the distribution power line network is underground, in a global context most networks are above ground. Medium voltage power lines pose the highest electrocution risk for birds when not constructed avian-safe. There is also a risk of collision, but generally less so than for high voltage power lines because the conductors are usually arranged at the same height and, compared to high voltage power lines, low above the ground.

Nest or roosting substrate
The base upon which a nest is built or birds use to rest and sleep, in this context power poles, platforms, boxes and latticework in electricity masts.

Neutral conductor
See ground wire.

Outage
Event that occurs when the energy source is cut off from the supply, see also fault.

Phase
An energised electrical conductor.

Phase-to-ground
The contact of energised phase conductor to ground potential. A bird can cause a phase-to-ground fault when fleshy parts of its body (or wet feathers of wing or tail) touch an energised phase and ground wire or grounded parts simultaneously.

Phase-to-phase
The contact of two energised phase conductors. Birds can cause a phase-to-phase fault when the fleshy part of their wings or other body parts (including wet feathers of wing or tail) contact two energised phase conductors at the same time.

Pole
A vertical structure, usually made of wood, concrete or steel, manufactured in various heights, and used to support electrical conductors and equipment for the purpose of distributing electrical energy.

Power line
A combination of conductors used to transmit or distribute electrical energy; normally supported by poles or lattice masts.

Problem pole
A pole used by birds for perching, nesting or roosting that has electrocuted birds or has a high electrocution risk.

Retrofitting
The modification of an existing electrical power line structure to make it avian-safe.

Separation
The physical distance between conductors and/or grounded parts from one another.

Structure
A pole or lattice assembly that supports electrical equipment for the transmission or distribution of electricity.

Substation
A transitional point where voltage is increased or decreased in the transmission and distribution system.

Switch (tower or gear)
An electrical device used to sectionalise electrical energy sources.

Transformer
A device used to increase or decrease voltage.

Transmission line
Power lines designed and constructed to support voltages >60 kV.

Volt
The measure of electrical potential.

Voltage
Electromotive force measured in volts.

Wrist or Carpal Joint
Joint in the middle of the leading edge of the wing of a bird.

Appendix 1. Locating Potential Conflict Hotspots Using a Basic National Scale Approach

A basic national 'conflict hotspot map' can be created by combining information on the national power line network, locations of Important Bird Areas (IBAs) and locations of Critical Sites for endangered (collision susceptible) species. Using Bulgaria as an example, we aim to show how a combination of basic data can generate a first insight in the locations of the potential collision hotspots. We derived information on the national electricity grid from ABS Energy Research (2011). Additionally, we mapped the Bulgarian Important Bird Areas using the data zone at the BirdLife International website. Finally, we used the Critical Site Network (CSN) Tool (an achievement of the Wings Over Wetlands (WOW) UNEP-GEF African-Eurasian Flyway Project) to derive maps of the Critical Sites in Bulgaria for two threatened species: Red-breasted Goose (*Branta ruficollis*) and Dalmatian Pelican (*Pelecanus crispus*).

The Bulgarian power line network

In 2010, the total length of transmission lines (in this case 110 kV and higher) in Bulgaria was 15,415 km (figure 1). The distribution line (in this case below 110 kV) length in Bulgaria in 2010 was 163,216 km (not shown in figure 1). The principal transmission system operates at 400 kV and covers all regions of the country along with a small length of 750 kV line. The high voltage grid comprises two rings, both passing through Sofia. While the main ring runs round the country to Varna and Bourgas on the Black Sea, connecting to the Ukraine line at Varna in the Northeast and to Turkey from Maritsa East in the Southeast, a second, smaller ring links Sofia to Kozlodui in the North and also to connecting lines through Romania. The system has links with Greece, Macedonia, Moldova, Romania, Serbia and the Ukraine at 400, 220 and 110 kV (ABS Energy Research, 2011).

Figure 1. Bulgarian transmission network. Source: NEK (ABS Energy Research, 2011). The distribution network is not shown.

BirdLife Important Bird Area (IBA) Programme

The function of the BirdLife Important Bird Area (IBA) Programme is to identify, protect and manage a network of sites that are significant for the long-term viability of naturally occurring bird populations across the geographical range of those bird species for which a site-based approach is appropriate. The IBA Programme is global in scale and, to date, over 10,000 sites have been identified worldwide, using standard, internationally recognised criteria for selection.

Using the mapping option at the data zone of the BirdLife International website (www.birdlife.org), we generated a map of the IBA's in Bulgaria (figure 2). For instance, many IBA's can be found in the Eastern part of the country close to the Black Sea, in the central mountainous part of Bulgaria, the Balkan Mountains and along the Southern border of the country.

Figure 2. Important Bird Area's in Bulgaria (green). Source: http://www.birdlife.org/datazone

Critical sites for endangered bird species (Critical Site Network (CSN) Tool)

The Critical Site Network (CSN) Tool is an online resource developed by Wetlands International, BirdLife International and the United Nations Environment Programme – World Conservation Management Programme in the framework of the Wings Over Wetlands (WOW) UNEP-GEF African-Eurasian Flyways Project, one of the largest flyway-scale GEF funded projects in the African-Eurasian region to date. This tool brings together several other data sources and so provides a user friendly means to investigate the importance of certain sites for (migratory) waterbirds. The CSN Tool strengthens the implementation of the African-Eurasian migratory Waterbird Agreement (AEWA) and the Ramsar Convention on Wetlands.

Sites included in the CSN Tool have been identified using two numerical criteria derived from those used for the identification of Ramsar sites and IBAs. They embrace breeding, non-breeding and stopover sites used by migratory species during their annual cycles as well as those used by resident species year-round (www.wingsoverwetlands.org/csntool).

Red-breasted Goose and Dalmatian Pelican

Two globally threatened species that are present in Bulgaria and that are potentially vulnerable to power line collisions are the Red-breasted Goose and the Dalmatian Pelican. Comparison of the locations of the Critical Sites for these species with the routing of the Bulgarian transmission network delivers information on the location of possible collision hotspots for these species.

The Red-breasted Goose has a moderately small population, which appears to have declined rapidly over a short time period. At the IUCN Red List of Threatened Species it is listed Endangered. In January and February, 80-90% of the birds now congregate at five roost sites on the Black Sea at Shabla and Durankulak in Bulgaria and Razelm-Sinoe lagoons and Techirghiol in Romania. Smaller numbers winter in Ukraine and in severe winters in Greece. (BirdLife International 2011, Species factsheet: *Branta ruficollis*).

For the Dalmatian Pelican, conservation measures have resulted in a population increase in Europe, particularly at the species's largest colony, at Lake Mikri Prespa in Greece. However, rapid population declines in the remainder of its range are suspected to be continuing and therefore the species is listed as Vulnerable on the IUCN Red List of Threatened Species. The Dalmatian Pelican breeds in Eastern Europe (also in Bulgaria) and East-Central Asia. European breeders winter in the Eastern Mediterranean countries. Collisions with overhead power lines are one of the known continuing threats for this species. (BirdLife International 2011, Species factsheet: *Pelecanus crispus*).

Bulgaria counts 12 critical sites for the Red-breasted Goose and 17 for the Dalmatian Pelican, of which eight are overlapping (figure 3). For both species most critical sites are located in the northeastern part of the country, with most sites located close to the Black Sea.

Figure 3. The Bulgarian critical sites for the Red-breasted Goose (orange), Dalmatian Pelican (pink) and both species (blue). (Sources: www.wingsoverwetlands.org/csntool).

Potential collision hotspots

We can now roughly determine the location of the country 's potential collision hotspots by combining the information on the national transmission line network and the information of the locations of the IBAs and critical sites in Bulgaria into one single map (figure 4).

In general, there appear to be no clear large collision hotspots in Bulgaria in which IBAs, critical sites and transmission network nodes are all located in one area. The largest node of transmission lines located at Sofia in the western part of the country does not seem to directly pose a large risk for protected areas (IBAs) nor for the Red-breasted Goose or the Dalmatian Pelican as the largest part of the lines is located outside the IBAs and no Critical Sites are located nearby. Also the second-largest node of the transmission network located in the southeastern part of the country, roughly in-between Stara Zagora and Yambol, is located largely outside IBAs and there is only one critical site for the Dalmatian Pelican located nearby (Ovtcharitsa Reservoir; figure 4).

Most critical sites for the Red-breasted Goose and the Dalmatian Pelican are located at the east coast (at the Black Sea) and at the Northern border along the Danube river. There is no large concentration of transmission lines close to these critical sites. There are, however, some critical sites that are located nearby one or two transmission lines. For example, the island near Gorni Tzibar (figure 4) in the north, which is a critical site for the Dalmatian Pelican, or the Atanasovsko Lake and the Burgasko Lake at the Black Sea (figure 4), which are important for both the Dalmatian Pelican and the Red-breasted Goose. In

such cases only precise site-specific studies, in which amongst others the main flight routes are mapped, can determine the collision risk for endangered and/or protected bird species.
Despite the fact that there are no clear collision hotspots in Bulgaria, several transmission lines are seen to pass through IBAs and may pose a risk for bird species for which these IBAs have been selected. Further research into potential conflicts at these sites is recommended.

While judging the information we have to keep in mind that because of the national scale of the maps we can only get a rough indication of the location of potential collision hotspots. Furthermore, it is important to realise that the distribution network is not shown, which makes that a large part of the potential danger for collisions is not indicated in the map and, therefore, not evaluated. However, altogether maps like these can be helpful as a tool to identify potential problem areas where more detailed studies are required or desirable.

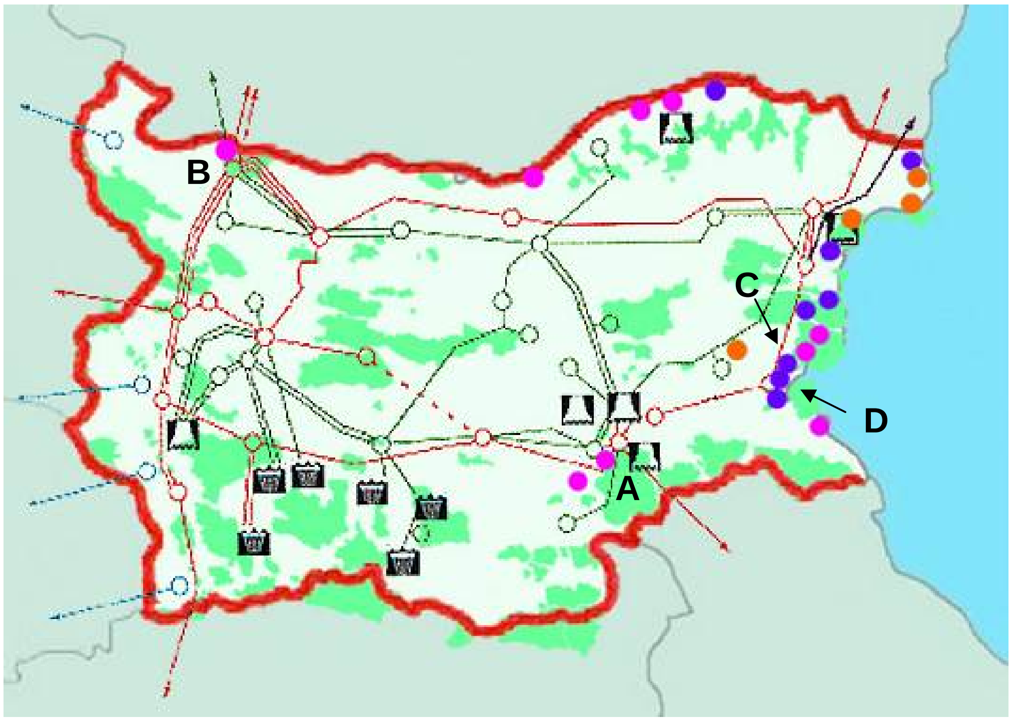

Figure 4. The Bulgarian transmission network (black and red lines), combined with the Bulgarian IBAs (green areas) and Critical Sites for the Red-Breasted Goose (orange dots), Dalmatian Pelican (pink dots) and both species (blue dots). A = Ovtcharitsa Reservoir, B = Island near Gorni Tzibar, C = Atanasovsko lake, D = Burgasko lake.