WILDLIFE INDUCED OUTAGES AND PROTECTION OF OVERHEAD LINES AND SUBSTATIONS

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Abstract:

The world's requirement for ever more reliable and cost effective operations continues at pace, with down time measured and penalized in minutes and seconds. In the last 20 years, an increasing realization within the industry better understands that the external, generally uncontrolled, effects of wildlife are responsible for a far greater amount of unplanned outages than previously acknowledged. As a result, wildlife and asset protection has become an area of increased interest given that reducing unplanned outages equates to improved efficiency.

Consider the following:

- The cost of a single outage can run into hundreds of thousands of $$$ (References 3,4,5,6)
- Potential fines for not adequately protecting wildlife <$500,000 (Reference 5)
- Wildlife outages per year number tens of thousands
- The global cost of wildlife induced outages per year >$10bn
- 50% of wildlife induced outages caused by birds.

Along with our better understanding of the challenges comes an additional pressure from environmental bodies who have the best interests of the wildlife at risk of being electrocuted uppermost in their arguments. Historically the area of concern was most often that of the electrical power provider whose reliability was the critical factor but today both points of view require consideration.

This paper deals with the wide range of applications where wildlife interact with our electrical network. We define the problem and illustrate the potential solutions using modern materials and design to enhance reliability while protecting our wildlife.

Introduction

Every power provider on earth suffers disruption from unplanned outages of one type or another. For many years these were categorized as weather, wildlife or unknown with limited detailed knowledge of the levels of each. We now have a far greater depth of knowledge of these "unplanned" events and studies now tend to categorize unplanned outages as follows: (In no specific order as we will see later that problem significance varies from country to country and even between regions within a country)

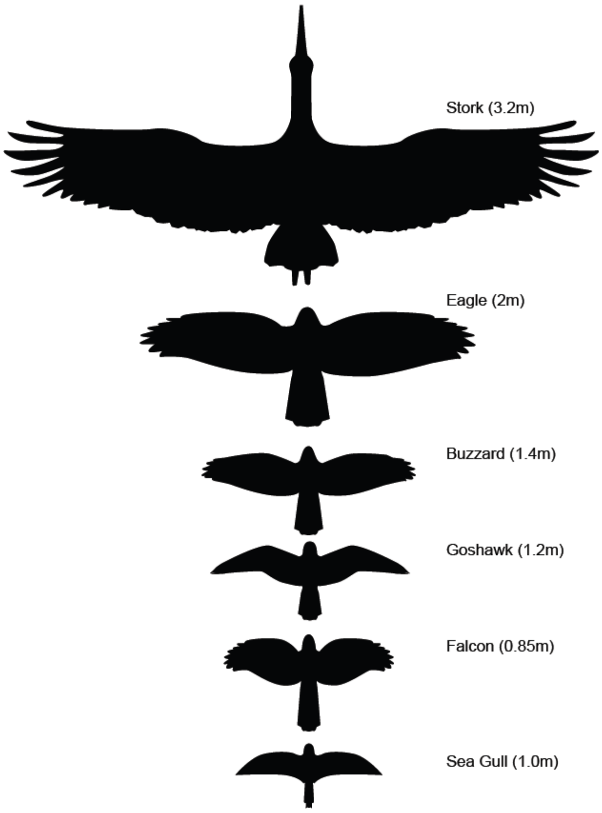
- Wildlife (Birds and animals)
- Weather (Storms, wind, lightning)
- Vegetation (Tree branches)
- Human intervention (Accidental and deliberate)
- Unknown or not categorized

This paper is primarily concerned with the problems, costs and long term solutions caused by wildlife (birds and animals). It will highlight various other sources where the outage/damage was caused by one of the other mediums but the solution would be the same as if a bird or animal was the prime cause.

Understanding the Problem

Broadly speaking the problems created by wildlife in substations and overhead lines fall into two categories, bridging and wildlife guano pollution flashover. The result, a system trip and possible arc flashover may be the same but the way it is brought about and the best solution often differs in how different products are applied to the different pieces of equipment that might be compromised.

Bridging is where a bird or animal makes contact between phases or between phase and ground creating a short circuit. The illustration below makes it clear how easily large birds can cause problems across all distribution voltages in substations and on overhead lines. Phase bridging usually results in the bird or animal being electrocuted and depending on how the dead bird or animal falls will determine whether the auto-reclosing system operates successfully. Often the bird or animal will fall away allowing the auto-recloser to re-energize the circuit as intended. Although this may not normally require investigation by emergency crews it usually leaves un-noticed damage. (Figure 1 shows typical "tell-tale" sign of wildlife induced damage)



Although a circuit may be operating normally a series of these events can lead to a build-up where the damage gets worse with each trip and finally causes a hardware failure, for example where each trip burns out a single strand of a conductor eventually dropping the line. If the dead bird or animal falls between its points of contact and remains there it will result in the circuit not being able to be re-energized and will stay like that until an emergency crew can remove the fault (bird or animal) and re-energies that circuit. At least this type of event can be logged with some certainty of what happened whereas the bird or animal that falls to the ground or on top of a transformer is quite likely to be removed by some predator. (Figure 2 shows a typical occurrence – before being removed)

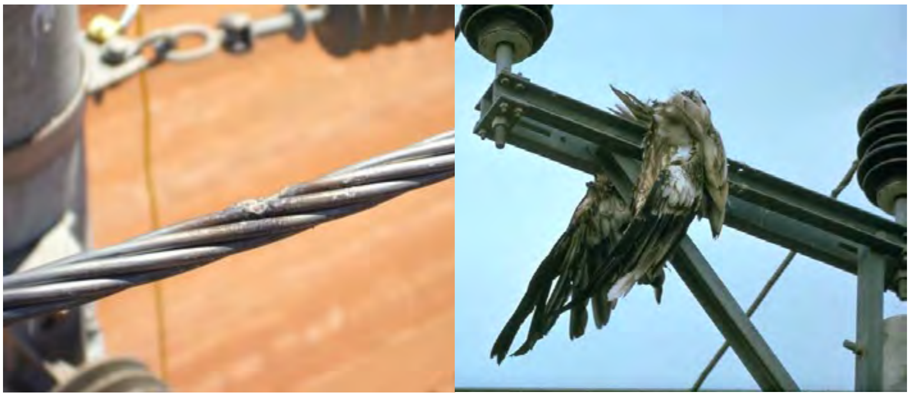


Figure 1. Damage to conductor known as "stranding". Figure 2. Dead bird fallen away from contact area.

Most bridging problems occur on Medium Voltage systems (typically <36 kV) designed where bare conductors, bushings, busbar systems and associated equipment have "air-spaced" clearances that under normal conditions operate without issue. Clearances are typically up to 40cm (Reference 1) in substations and approximately 1m for overhead lines to allow for swinging conductors. These clearances unfortunately allow a wide range of birds and animals to cause huge problems in substations and birds predominantly on overhead lines. It should be noted that although overhead line conductors are typically 1m apart, the most common failure mode is between the cross arm (usually grounded) and conductor, which is typically 30 to 40cm.

Medium and large size birds stand on the cross arm and bridging usually occurs during landing or takeoff when the bird has open wings. In more unusual cases other wildlife such as bears, possums or snakes can climb the poles and cause similar problems. These are very location specific.

Pollution flashover is a far less frequent occurrence but can be every bit as damaging as bridging induced outages. It is mostly associated with insulators on overhead lines but can in specific situations occur in substations. It also differs from bridging in that it occurs across all voltage ranges right up to transmission levels at VHV.

NB: The type of pollution flashover considered in this paper is only that associated with bird guano and not to be confused with the more common use of the term when describing airborne contaminants such as salt in coastal environments.

Pollution flashover takes place on a bushing or insulator when bird guano builds up over a period of weeks or months during dry conditions when there is little or no rain to wash the porcelain or glass. Birds often favor certain places to perch and this is often at the extremity of a lattice tower arm directly above an insulator string. Over time the build-up of guano can be considerable (see Figure 3), but while conditions are hot and dry the relatively small individual amounts of liquid guano quickly dry and the surface resistance level is not greatly altered.

Figure 3. Guano build-up on suspension insulator and on substation equipment.

Flashover can occur after this period of dry weather when mist, fog or rain first returns which has the effect of changing the dried guano into a semi-liquid state and greatly reduces the surface resistance of the porcelain or glass. If the build-up of guano is enough once moisture is present to change the conductivity of the whole insulator string, flashover can result. It should also be noted that another bird related failure mechanism that of “Guano Streamers” can cause flashover when a bird perched above an energized conductor emits a liquid streamer up to 2m long (Reference 2) which can effectively short out the otherwise safe air gap.

All countries see some level of wildlife caused disruption but the diverse nature of the bird or animal causing the problem plus the different types of equipment found in different countries and the different environmental conditions means often different approaches are required for prevention. Fortunately, once a failure mechanism is recognized modern materials and designs make it preventable to a very high degree, often for the remaining life of the equipment.

The diverse nature of problems from around the world

The range of problems caused by wildlife and experienced by substation and overhead line engineers who have to deal with them is enormous. This paper can deal with a limited amount so will look at some of the most common, but gives a flavor of the diverse issues seen. Problems related to wildlife can be categorized as: migratory related, local specific, food (predator or prey), shelter/security/nesting, seasonal, other.

Migratory issues concern birds almost entirely. Birds passing through an area to a final destination often stop to feed and rest and in these short periods of time can cause havoc locally by overcrowding mast tops where there is limited perching space available and either bridge phase to ground or between phases. Other incidents include flying into overhead lines near feeding sites, usually at distribution voltages where conductor clearances are such that large birds flying into them can bring two conductors together resulting in flashover (see figure 6)

Once birds have completed their migration journey they tend to return to the exact same location year after year, which means even if old nests are removed once the birds have gone they will build from scratch the following year on that same pole or tower. The exact nature of failure depends on the design of equipment, type of bird, voltage etc. but can be simple bridging while perching on an medium voltage cross arm, guano induced failure most often on high voltage suspension towers, nesting materials falling out of nests as the nest structure grows or groups of birds flying in and around jumpers where there is a switch or pole top transformer.

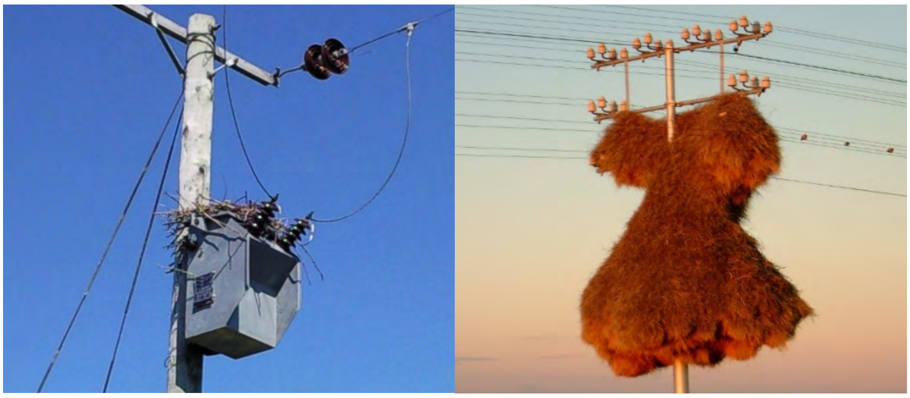


Figure 4. Pole top transformer nest site and huge nest structure in South Africa.

Figure 5. Migratory stork nest in Greece and griffon vulture fatally bridging in Israel.

Figure 6. Pelicans dead from clashing conductors, Israel and nest likely to cause flashover, Spain.

Absolute data regarding the number of birds killed worldwide is usually under reported as many countries either do not record accurate statistics, or fear publication due to regulatory consequences. From the data that does exist it is clear that a figure measured in tens of millions (Reference 3) of birds killed per year is beyond question and from the viewpoint of the electricity suppliers this equates to annual costs of >$10 Billion (Reference 4). The additional costs include: lost revenues from sale of electricity, damaged equipment, call-outs by line crews and fines imposed.

Some countries use legislation to protect its endangered wildlife with severe fiscal penalty (Reference 5) up to $500k.

Problems in substations are almost exclusively of a bridging nature where birds or animals bridge phases or phase to ground. Issues are generally not migratory related but can be seasonal, e.g. during cold weather when cats and other similar size creatures are attracted to the warmth that being close to a transformer offers. It is considered seasonal when for example small birds build nests and a range of predators, depending on the location, such as cats, martens, snakes, birds and other species are looking for a food source to feed their own young.

In medium voltage substations as a rule of thumb, anything up to 40cm between phases or phase and ground is considered vulnerable to bridging by wildlife. This can of course be a far greater distance, perhaps up to 1m if the substation in question is plagued by wildlife that can bridge much farther such as snakes, monkeys and large birds of prey.

It would be possible to show examples of a huge number of bird and animal related issues from different countries, different equipment and different species, but this paper will only show a snapshot of what happens and then concentrate on the best solutions that are proven to reduce these instances where they are employed. Figures 7 & 8 show some typical substation related issues.

Figure 7. Monkeys in Indian substation and evidence of inter-phase bridging, Greece

Figure 8. Phase to ground bridging in the U.K. and in Germany

Solutions for prevention using latest material design

Considering the huge cost to society in terms of finance, wildlife and inconvenience it might come as a surprise to some that almost all the problems we see as a direct result of bird or animal interference is completely preventable. When you consider the industry estimates the cost to be in excess of $10 billion annually it might be expected that more was being done to prevent it?

The best solution is one that allows whatever wildlife is causing a problem to safely access their chosen sites and not cause electrical breakdown of any part of the system. It is equally important that any solution is cost effective such that installing it costs considerably less than the cost of the possible outage it may prevent. It is impossible to put a cost to every problem because of the diversity of issues, varying from $1k to in excess of $1 million, but an average of circa $10k (Reference 6) is used in the USA where the majority of the data originates.

The importance of the material used cannot be underestimated. The solution to the wildlife problem must not cause downstream issues because of material failure. On “day one” almost any solution will perform to some degree, but the solution that is most effective will continue to work maintenance free for the lifetime of the equipment on which it is installed. This will often mean having to work for at least 20 years and often longer in some of the most challenging environments on earth such as extremes of hot and cold, severe weather, long term U.V. exposure and in a variety of polluted conditions especially uric acid (bird guano).

With these environments in mind, materials need to exhibit a minimum of technical criteria according to relevant international standards:

Test description	Testing standard	Test result	Important because
Tracking and erosion resistance	ASTM D2303	1 hour @ 3.00kV	Most products sit between phase and ground and see leakage currents
U.V. stability	ASTM-G154	100% @ 75k hours	Long term exposure in climatic extremes Maintain high degree of flexibility
Thermal endurance	ASTM D638	105°C continuous	To endure periods of high temperature both ambient and current maximums without distortion or melting
Ultimate elongation	ASTM D638	300% target	Maintain high degree flexibility
Dielectric strength	ASTM D149	13kV/mm	Minimum insulation value

In addition to an optimized geometry, the material should target performance consistently without electrical or mechanical breakdown for over 30 years. TE Connectivity’s, Raychem family of high performance polymers is one such material range which has exhibited excellent performance since its launch in the market in the 1960’s. The materials are mechanically robust, maintain excellent electrical properties and are highly tolerant to wildlife exposure.

The photos below illustrate what can happen in a very short time when the minimum levels of material performance are not met.

Failure by tracking

Failure from U.V.

Failure by erosion

A variety of solutions have been tried in the last 20 years (Reference 7) including sonic deterrents, barriers, covers, electric fences, smooth climbing barriers, chemical barriers and spine perching devices, many of which are designed to drive the bird or animal away from a specific place only for the problem to re-appear elsewhere. There is also the consideration that migratory birds in particular and some resident animals always return to the same nest or feeding sites, this simply reinforces the importance of a solution based on protecting the reliability of electricity supply while allowing the wildlife unhindered access where it may choose to climb or fly.

Many of the tried solutions have limited, short term or localized benefits but the most successful overall solution (Reference 8 & 9) is one where a range of electrically high performance polymeric materials designed for some specific and some range taking applications are implemented. The critical material performance factors must include excellent long term ageing where a material is expected to maintain both its electrical and physical properties, thermal endurance (continuous operating at up to 105°C) and high U.V. stability after 30 years in the field.

In parallel with outstanding material performance is the importance of good design. The key to successful prevention of bridging or guano flashover is understanding the problem which means knowing where the most vulnerable bare metal places are that need insulating. Depending on the precise nature of the problem, perhaps a cat bridging phase to ground on an medium voltage breaker or white stork sitting atop a cross arm making contact with one or more phases, the solution may vary and the local substation or overhead line engineer is key to gaining this information along with that from the tell-tale signs mentioned earlier.

Vulnerable bare metal components can be insulated quite easily with either heat shrink, cold applied or a combination of these materials and typically up to 30cm further along the busbar or overhead line than the farthest known fault location. This is general guidance and local knowledge should always be taken into account where it is available. In bridging situations between phase and ground it is far more common to protect both equipment and wildlife by insulating the live side, e.g. busbar or conductor but it is perfectly acceptable to insulate the grounded side instead.

Actual long-term solution

The following are examples, with detailed explanation, of insulating vulnerable bare overhead lines and substation equipment metalwork that had previously been subject to multiple flashovers or were deemed high risk of doing so. In all cases the insulating materials applied have eliminated the problem while allowing the wildlife to continue access as it wishes.

Pages 8 & 9 look at typical overhead lines issues/solutions.
Pages 10 & 11 look at typical substation issues/solutions.

Example 1: Migratory birds

A white stork has a 2m+ wing span and thousands migrate from Africa to nest in Spain, central and South-East Europe every year. Its nest is so big, up to 400kg (Reference 10) and 2m in diameter, it would cause flashover at some point either from accidental bridging between nest debris and conductor when conditions are wet or from birds bringing pieces of conductive material e.g. wire to the nest or from the young birds that stray around the nest site prior to fledging and contact a conductor. By insulating the bare metal fittings with a wraparound cover and the conductor with wraparound sleeking approximately 1.5m away from the nest in both directions the bird and system have long-term security.

Example 2: Common occurrence, a crow's nest

This crow's nest in South Africa on a 66 kV line between insulator and pole is precariously positioned. The wings of the bird during landing or take off from the nest is likely to cause accidental bridging at any time. Without the combination of conductor sleeve and wrap around connection cover this bird/nest combination would at some point cause flashover. The nest while dry conditions last may not cause a problem, however, once conditions become wet (rain, mist, fog etc.) it is likely to short out enough of the insulator to cause flashover. Even if dry conditions remain once the young birds are big enough to move about it is almost inevitable they will cause a flashover.

Example 3: Bird protection in Germany

Utilities in Germany are required by legislation to implement counter measures to prevent electrocution of birds and protect both migratory and domestic species.

The solution is to use protection that prevents electrocution of birds (Reference 12) on the 10/20 kV distribution mast tops. This is achieved by preventing accidental contact between the bird and live conductors, providing insulation covers with an overall length of approximately 1.4m. There are many designs that can be attached by cable ties (left photo) or with insulated poles (hot-sticks) with the system energized. It is also possible to use transparent materials (right photo) that allows aerial inspection of the overhead lines in terrain difficult to access. This may become more widely used as some utilities introduce "drones" for aerial surveillance.

Example 4: Bird guano

This insulator string demonstrates how the entire length of string can become heavily polluted with bird guano if not protected, the second photo shows that by shielding an insulator string it is possible to keep the surfaces clean enough to never suffer pollution flashover. It is critical the material and design of the shield give many years of maintenance free service, ideally made of high performance U.V. stable polymer and robustly secured at the top of the string. After seasonal rain storms the guano will wash away and fall harmlessly away from the string below. In countries of extreme dry conditions where it might only rain heavily once in several years it is even more important to use a material of high U.V. stability and resistance to uric acid (guano).

Example 5: Urban substation protection

This substation in Croatia shows all bare live metalwork insulated, busbars with heat shrink tubing, connection points with cold applied wrap around covers that can be removed for maintenance or inspection and re-used. The issue was phase to ground clearances on medium voltage side of transformer and bus network where typical 40cm air gaps were being bridged by cats and birds (crows & pigeons).

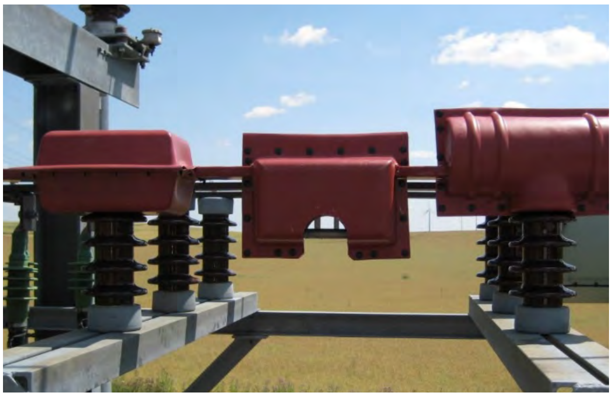
Example 6: City center substation

An ageing medium voltage substation in central Athens with huge numbers of cats and pigeons. Many phase to ground clearances well below the nominal 40cm distances and previously suffered multiple flashovers. Solution was to cover the vulnerable bare metalwork with a range of high performance polymeric covers, wraparound sleeking and circular barriers that prevent cats climbing over the insulator and being able to touch Medium Voltage and ground at the same time.

Example 7: African rural substation

This new medium voltage substation in South Africa was built on an area of cleared scrub and trees inhabited by a troop of large monkeys. In the first year of operation it suffered 12 flashovers caused by monkeys that considered this their territory. The solution was to insulate all live bare metalwork across the site with a combination of heat shrink tubes and several wraparound covers. Fully understanding the situation was critical to the success on this site because the phase clearances in some parts were approximately 1m which normally would not require insulating but as the main problem was large monkeys they can easily bridge a 1m gap.

Example 8: 20 kV substation in rural Germany



This 20 kV substation in rural Germany is insulated against climbing animals such as martens and cats using wraparound covers that are field cut on site to accommodate any unusual geometry including the center cover where a cut-out has been added to allow access for an earth clamp in a relatively safe position. Covers that need field cutting benefit from being produced from a polymeric cross linked material because they will never propagate splits if they are roughly cut.

Conclusion

Every utility in the world must contend with wildlife in the design and protection of their networks. In finding solutions, the utility must balance the need for exclusion/prevention and tolerance of the wildlife in question.

Globally, the evidence is mounting that wildlife causes a large number of unplanned outages, with the resulting costs to the power suppliers and their customers.

The main causes may vary from region to region, but the implications and design principals deployed to provide solutions are the same.

In addition to reliability enhancement and asset protection, it is clear that an unacceptable number of birds and animals are killed every year due to electrocution.

Legislation regarding protection of many species is increasing with countries like the USA and Germany leading the way, having already implemented detailed protection regulation. Wider EU legislation regarding bird protection is planned.

Awareness of cost of wildlife induced outages is growing and with that is an increasing demand for reliable and robust solutions to protect both the utility assets and the problematic wildlife.

As with any high voltage utility component, the material choice must ensure that the component material will not break down and cause a reliability problem during the lifetime of the network. With this in mind, it is just as critical to specify suitable materials similar to those used in other OHL components like insulators and arresters.

Wildlife induced outages are now entirely preventable.

References

(1) Barrett D.C: Improving distribution networks, 2003

(2) INMR: July 2015

(3) Manville A.W: Bird strikes and electrocutions, 2005

(4) Eaton: Blackout tracker annual report, 2013

(5) U.S. Fish and wildlife service protection act

(6) IEEE 1264 – 1993

(7) Baht O: Measures implemented to prevent electrocution of large and other soaring birds in Israel, 2003.

(8) ENDESA: Stork nesting impact on quality of electrical service. 2006

(9) ENDESA: Nest size, stork nesting impact on quality of electrical service, 2006

(10) E VDE-AR-N-4210-11

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