# Power Line Failures/Faults and Wildfire Initiation Mechanisms

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Wildfires are one of the most hazardous natural disasters in Australia in terms of fatalities, property damage and financial losses. Events of catastrophic wildfires are recorded across the world including in the United States and Canada. Failures along power distribution infrastructure and network faults have been identified as some of the causes for the initiation of wildfires. Thus, it is critical to better understand the mechanisms and the potential prevention strategies for wildfires caused by power distribution system faults.

wildfire | electrical apparatus failure | power distribution infrastructure failure | conductor failure | vegetation related faults

## 1. Introduction

Wildfires are identified as one of the most hazardous and catastrophic natural disasters. Events of wildfires have been recorded around the world over the years [1][2]. Nevertheless, Australia, the United States and Canada are among the top in the list of countries prone to wildfires given their topography, climate and vegetation patterns [3][4][5][6]. Australia has a history of a long line of events of large-scale wildfires occurring in the days of elevated temperatures and extreme weather conditions as it is the driest continent in the world. Among these events are the 1939 wildfires in the states of Victoria and New South Wales, 1967 wildfires in Tasmania, 1977 wildfires in Victoria and “Ash Wednesday” and the 1983 wildfires in Victoria and South Australia [7][8][9]. More recent wildfires include the devastating “Black Saturday” 2009 wildfires in Victoria and the 2019–2020 wildfires in New South Wales [10][11]. These wildfires have collectively resulted in hundreds of fatalities, thousands of houses destroyed and millions of dollars in economic losses. The greatest tragedy of the Black Saturday wildfires in 2009 was that it alone destroyed over 1800 homes burning over 270,000 ha of land and causing death for 173 people [10]. Further, the catastrophic wildfires of New South Wales in the recent wildfire season (2019–2020) in Australia have damaged over 3000 homes, claimed 34 human lives, more than 1.25 animal lives and caused an economic loss of over $110 billion [10][11]. It is evident from these data that the persistence of wildfires in Australia continues to pose enormous socio-economic impacts.

The temperature and rainfall preceding a wildfire determines the size and duration of the wildfires [12]. Further, the wind speed is a crucial factor in determining the spread of wildfires [13]. There are numerous causes of the initiation of wildfires among which some are natural causes such as lightning, which are inevitable [14][15]. Deliberately lit fires and human errors also account for a significant portion of the known fire causes in Australia [16][17]. Some examples of human errors which can lead to wildfires include improperly discarded cigarettes, unattended campfires and the burning of debris [18]. Power distribution system faults and the failure of power distribution infrastructure, especially during elevated fire danger conditions, can result in the initiation of wildfires [19]. There is a wide variety of issues which might cause power distribution system faults. The root causes can be categorized as vegetation-related faults, electrical apparatus failures, pole and crossarm related failures and line failures [1][20]. Vegetation-related faults typically occur when a conductor in an electricity distribution system breaks and touches the ground or leans and touches an overgrown tree branch [21]. In addition, fallen trees or tree branches on conductors can result in faults. These faults are commonly known as High Impedance Faults (HIFs). Electrical apparatus failure refers to the failure of power network equipment such as overhead lines, switches, breakers and capacitors. Further, the explosion of transformers falls into this category. The failure of poles and crossarms is mainly due to their degradation over the service life resulting in the loss of structural integrity. Overlooked defects in this infrastructure can cause structural failures, leading to the loss of capability to support overhead conductors. Moreover, leakage current in wooden poles and insulator contamination can cause pole-top fires which can create severe safety concerns [22]. The detection and prevention of these faults is paramount to mitigate the threat of wildfire initiation and, thus, government authorities continue to pay attention to this. For example, the Victorian Bushfires Royal Commission [10], appointed after the devastating “Black Saturday 2009” wildfires in Victoria, provided special recommendations to prevent or at least to mitigate electricity-caused fires. Among these recommendations are to improve the monitoring and surveillance of power distribution infrastructure.

The failure or faults in power distribution infrastructure can initiate wildfires. Multiple ignition mechanisms are possible considering different root causes. The aforementioned mechanisms are broadly grouped as: vegetation related faults, electrical apparatus failures, overhead cable supporting infrastructure (poles and crossarms) failures and overhead cable failures.

## 2. Vegetation Related Faults

Wildfire initiation can take place in different ways due to overhead powerline vegetation-related faults. Characteristics of the vegetations and their ignition features dominate the potential of these faults [23]. The occurrence of vegetation-related faults is twofold. One way is by direct contact with conductors which results in high-impedance fault-to-ground and if this is continued for a reasonable time it can result in flashover. The other way is when fallen trees or broken tree branches land on the overhead cables causing conductors to make contact with each other [24]. Mechanical tear down of conductors by falling trees or branches has been estimated to cause about 80% of all vegetation-related power line failures [20]. **Figure 1** illustrates photos of conductor flashover due to vegetation-related faults. These faults are crucial, especially under elevated wildfire danger conditions such as strong winds and high temperatures. Under these conditions, even a small spark can initiate a wildfire which can subsequently lead to a widespread catastrophic wildfire.

**Figure 1.** Vegetation-related faults and flashover in conductors [20].

A wildfire initiated by vegetation-related faults is driven by a few main factors such as: fuel and its availability to burn, sources of ignition and prevailing weather conditions [25][26]. Fuel and its availability are highly variable both spatially and temporally due to relying on complex physical and biological processes [27]. Fuel arrangement in vegetation can be divided into five main strata: overstorey fuel (trees), elevated fuel (young trees and shrubs), near-surface fuel (herbs and grasses), surface fuel (ground leaf litter and fallen bark) and bark fuel (bark on tree trunks and branches) [28]. The fuel arrangement also greatly varies from place to place, similar to fuel availability. For example, in Australia there are regions of dense rainforests, grassland savannas and open woodlands. Fuel quantity/fuel load relies on the type of vegetation and a dense forest has more fuel than an open forest. In western Australia, Jarrah forests accumulate fuel at a rate of around 1–2 tons per hectare per year whereas Karri forests have a fuel load around 3–4 tons per hectare per year [29][30]. In addition to the type of vegetation and corresponding fuel load, type of fuel also dominates the intensity and spread of wildfires. Fuel type can be characterized as fine or coarse [31]. Fine fuels are less than 6 mm wide and consist of dead leaves, dead grass and twigs. Coarse fuel consists of fallen logs and tree branches which are far less combustible than fine fuels. Fine fuels dry out fast and can catch a fire and burn easily. Despite fuel type, dryness of fuel is also a crucial factor determining the rate of ignition. The dryness or the moisture content of fuel is heavily influenced by climate and local weather conditions. Further, characteristics of the vegetation also affect the moisture content of fuel. Some plant species are relatively drier than others naturally [32].

## 3. Electrical Apparatus Failure

Power distribution networks consist of different electrical equipment such as transformers, breakers, switches, bushings, clamps, capacitors and many more. Faults in this equipment can lead to overheating which can ultimately end up with burning, arching or explosion. Falling down of the hot molten or burning parts on ground or vegetation can lead to the initiation of wildfires. Among different components, transformers have been identified to be more susceptible to explosions and fires [33]. In addition to transformer explosion, bushing flashover has been observed as another common example of electrical equipment failure [20].

## 4. Power Distribution Infrastructure Failure

Utility poles and crossarms are the structures supporting the overhead cables. Most of this infrastructure is made from timber which is a bio-degradable material subjected to deterioration over the service life. Failure of timber poles can take place under normal conditions due to overlooked defects resulting in false conclusions about the structural integrity. Their failure rates can be high, especially under low frequency extreme weather events such as hurricanes. Moreover, vehicle crashes can result in the failure of timber poles. The failure of poles or crossarms can result in the conductors being grounded or conductors coming into contact with each other leading to flashover or arching.

## 5. Conductor Failure

Conductor failure can take place, especially under high wind conditions. When the conductors are loose, high swinging can take place, resulting in the distension of cables and the bending of supporting structures. Arching can take place if contact occurs between energized conductors, and clashing power lines are likely to emit particles capable of causing wildfires [34]. In addition to high wind conditions, conductor clashing can occur due to short circuits in a power system leading to electromagnetic forces between conductors. These electromagnetic forces subsequently lead to conductor swinging which creates the possibility of arching.

The aforementioned mechanisms can occur alone or in combination with each other. For example, in the event of extreme wind conditions, there is a possibility of fallen trees or branches on conductors causing vegetation-related faults. Meanwhile, higher wind speed can lead to a higher probability of utility pole or crossarm failure. Thus, power distribution infrastructure failure is also possible under high winds. In addition, conductor flashing is another possibility due to the high swinging of cables and contact between energized conductors. Therefore, more than one mechanism can take place simultaneously under certain conditions. Among the different types of wildfire initiation mechanisms due to power line faults, vegetation-related faults are the most common and significant factor contributing to wildfires. This has been identified as the main cause for many large-scale wildfires spread in Australia [10][11]. In terms of the frequency of occurrence, the second dominant cause for wildfire initiation is the conductor failure. Conductor failures can generate sparks and these can initiate wildfires in elevated wildfire danger conditions. Electrical apparatus failure and power distribution infrastructure failure can be rated as the next influential mechanisms of wildfire initiation due to powerline faults. When assessing the risk of wildfire initiation due to power line faults, the aforementioned order of causes needs to be considered according to their significance.

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