Fire in the Sky

The bushfire threat from wind generators.

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Introduction

I have been asked to comment upon the consequences of a fire in the hub of a wind generator under conditions suitable for the spread of bushfire.

The power industry is no stranger to the threat of bushfires both from being a source of ignitions and suffering considerable damage to their distribution networks.

The threat

Electrical conductors are a well known source of bushfires as was demonstrated for example in 1983 when extensive fires were started in South Australia. Fires started when high winds, high temperatures and dry air combined to cause conductors to clash and short circuit, sending hot molten metal to ignite vegetation. Trees and tree limbs were also blown onto live conductors and caused elevated ignitions, which subsequently fell onto grass and caused massive and damaging fires.

The resulting fires, mostly in grass lands but also in scrub and forest spread rapidly and beyond control and caused many tens of millions of dollars damage to pine plantations, towns and the passage of fire resulted in many tragic deaths.

Another series of major fires occurred when normally safe railway diesel locomotives caused multiple ignitions when the fire weather reached into the “extreme range”.

In both the power line and the railway diesel engine ignitions there was probably no clear expectation that a threat existed, and none did until the fire danger reached ‘extreme’ levels.

In the case of wind generators if there is a measurable likelihood of fires occurring and with the lack of constant supervision of such high energy equipment it would be a real expectation that the owners of the generators would be liable for all the fire damage, which could reach into the billions if they caused fires on days of extreme fire danger.

The only safe risk management strategy would be to disconnect the generators and feather them when the McArthur fire danger index reached a level where fire fighting would fail in the particular fuels.

It would also be prudent risk management to ensure that no burnable fuel was within reach of burning embers dropped from hub height and transported with high-speed fire winds during fire danger periods (usually December to April, in Victoria).

Threat Areas

The winds in Victoria that generate the worst fire threat in Australia and arguably in the world, are the result of hot dry desert winds blowing from the northwest taking fire to the southeast. Most of the fire area and damage often occurs after a southwesterly wind change that accompanies a cold front that turns the milder flank fires into violent and destructive headfires. Hence the areas at threat as a result of a fire in a wind generator are those areas to the south east and east of the failed generator.

How big the threat?

It has been reported that about 20 turbines catch fire and burn each year. The global total number of turbines appears to be around 68 000. All these figures are World Wide Web data and some from Wikipedia. They provide a rough guide to quantifying the bushfire risk but should not be taken as definitive. Applying the global data to the 2000 or so turbines installed in Australia we would expect a 60% probability of one turbine fire each year.

A metrological study should be made for each windfarm site to determine the proportion of time that exceeds a forest Fire Danger rating of 6 or a grass Fire rating of 50. I would estimate that a FFDI of 6 and above would occur on more than 50% of summer days and GFDI greater than 50 on 10% of summer days.

We can expect (if my estimates are at all close to the mark) to have a 2% probability of an unstoppable bushfire if the turbine is in a forest area and in grass lands a 0.4% probability each year for grasslands.

What can be said is that from the time of failure until the time of fire brigade attendance a fire on the ground in extreme fire danger conditions would have spread beyond any possibility of control.

The problems confronting the fire agencies are increased by the lack of accessibility to the burning turbine and in many cases the ground in the vicinity of the turbine.

Limits to control

Assuming that a failure has occurred, a fire having started and a brigade in attendance there is a fire intensity beyond which fire fighting is totally ineffective and is of such a risk that firefighter withdrawal is the only option. The fire intensity at which that occurs appears to depend upon the type of bushfire fuel. It is known with some reasonable certainty that the limit to fire fighting in dry eucalypt forest is around 2.5 megawatts per meter when measured by the Byram Line Fire Intensity Index (I Mega watts per meter) where

$$I = Hwr$$

H is the calorific value of the fuel, which for practical purposes is 18 Mega joules per Kilogram, w is the fine fuel consumed in the flame front and typical values could be 0.3 kilogram per square meter for grass lands (3 tonnes per hectare) and 2.5 kilogram per square meter for typical Victorian dry eucalypt forest (25 tonne per hectare).

Based upon firefighter opinion it seems that the critical fire intensity for grasslands could be as high as 10 Megawatt per meter. However unlike the critical level in dry eucalypt forest it has never been measured in Australia.

Let us assume that the fire started by a failed wind generator is in an exposed location and in grassland.

Rearranging the Byram intensity equation the critical rate of spread is given by

$$r = I / Hw.$$

Now H= 10 megawatt/meter and w = 0.3 Kg per square meter then

$$r = 10/(18 \times 0.3) = 1.85$$

That is 1.85 meters per second or 6.7 kph. Such a grass fire is not unusual. The McArthur fire danger meter (Mark3) (which is the basis for fire danger forecasting in Australian grasslands) predicts that the critical rate of spread will occur when the temperature is 38^{o}C, the relative humidity 10% and for 'average'pastures the wind reaches 29kph.

It is possible to use the equations of Noble, Bary and Gill[1] to estimate the critical McArthur Grassland Fire Danger Index. For the 'average' pasture case above, the generators would need to be removed from service if the McArthur GFDI exceeded 52 at a wind speed of 29kph. That is just into the extreme range when Total Fire Ban days are declared.

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1 Noble,I.R., Bary,G.A.V. and Gill,A.M. (1980) McArthur's fire-danger meters expressed as equations. Australian Journal of Ecology, 5, 201-203.

Similar calculations can be made for critical conditions in forestlands where the maximum fightable fire intensity has been measured at 2.5 Mega watts per metre. For forests the critical rate of spread in fuels of 25 tonne per hectare will be given by …

r = 2.5/18 X 3.0 = 0.046 meters per second i.e 167 meters per hour.

In the case of a wind generator in forest or scrub the critical Forest Fire Danger Index[2] would be 6. In the dry summer if the temperature is above 25^{o}C and the relative humidity is below 45% a Forest Fire Danger Index of 6 will be exceeded for any wind above zero.

The Bureau of Meteorology provides routine forecasts of the Grass Fire Danger Index and Forest Fire Danger Index and real time observations of the Forest Fire Danger Index across the state, all available of the web. Any failure to remove the generators in the light of the fire weather warnings would have to be critical in considerations of legal liability if a failed generator started a massive bush or grass fire.

Conclusion

If there is a known risk of wind generator fire then the generators must be disabled well before conditions reach critical being a Grassland fire danger Index above 50 or a Forest Fire danger Index above 6 for wind generators in forest or scrub areas.

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[2] A.G.McArthur (1973) Forest Fire Danger Meter Mk.5