SafetyOn Research report

An investigation into the root causes of fires in MW scale wind turbines

SafetyOn

In partnership with

energy institute

SAFETYON
RESEARCH REPORT: AN INVESTIGATION INTO THE ROOT CAUSES OF FIRES IN MW SCALE WIND TURBINES

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1 EXECUTIVE SUMMARY

In 2008 the Health and Safety Executive (HSE) issued a letter to the British Wind Energy Association relating to the potential risks of locating high voltage (HV) switch gear internally in wind turbines. In 2018 a second letter from the HSE was issued to the industry providing more detailed direction of how switchgear risks should be managed should internal location of switchgear be the only option. SafetyOn has worked with the HSE to identify the root causes of incidents reported within the last five years and better understand the risks. The aim of this study is to provide a balanced view of the risks and mitigations relating to switchgear located both internally and externally to wind turbines.

The data available within the industry is fragmented and difficult to surface, even with the major industry organisations involved. Nevertheless, 83 % of the RIDDOR/ESQCR reports from the last five years, identified as potentially relevant, are included within this analysis.

A significant cluster of reported incidents in the last five years, which have resulted in the complete loss of a wind turbine, is associated with cast resin transformer installed in one specific product range. The root causes of these incidents have been addressed through design change and a retrofit programme.

Technicians have been found to be most at risk during low voltage (LV) switching and re-energisation following repairs. Mitigation through safe positioning should be taken into account during these operations. Where this is not possible PPE rated to withstand arc-faults should be utilised.

There is little evidence within the data to demonstrate significant benefits from external siting of transformers, especially now that oil filled transformers are industry legacy. The fire risk from modern dry-type and liquid-immersed (e.g. MIDEL) transformers is significantly reduced compared with the older oil filled transformers.

2 ACKNOWLEDGEMENTS

We would like to thank the Health and Safety Executive (HSE) UK for providing access to industry data reported through the RIDDOR and ESQCR authority reporting mechanisms and SafetyOn TAC members for providing further details on incidents. Special thanks to David Goodfellow, B.Eng. C.Eng. MIET MBA (Nordex) for drafting the research report and to subject matter experts from EDF Renewables who assisted in reviewing and facilitating this research report.

3 METHODOLOGY

A database was created of all incidents reported through RIDDOR and ESQCR authority reporting mechanisms, and further details sought for each incident from members who had an involvement as OEM, operator or owner. A list of dates and report texts was provided from HSE records, but this did not include details of machines, sites or companies to avoid confidentiality issues. A separate list of site names affected was later supplied by the HSE.

SafetyOn members were asked to identify issues concerning their sites or turbines. As well as understanding the root cause, key risk based parameters were identified and evaluated for each identified case:

– was the turbine manned during the incident;
– was the HV equipment internal or external;
– would the effects have been significantly different if they had been located differently.

In parallel, a search of databases compiled by organisations opposed to the development of windfarms and other internet materials was performed to identify further descriptions of the incidents.

The data was categorised using the following categories:

Date	
Detail	Text field with the RIDDOR/ESQCR report text (from HSE)
Root cause	Open text field
Site name	
Turbine model	
Description	As received from SafetyOn members
Involved	Operators/Site Managers/OEMs
Manned flag	Was the turbine manned at the time of the incident
Root cause	As received from SafetyOn members
System	Dropdown selection to define area where incident occurred

Categories
Bearings
Converter
Generator cable box
Generator slip ring
HV cables
HV switchgear/RMU
LV cables
LV switchgear
Main brake
Main transformer

Effect Dropdown selection to define effect of the incident

Categories
Trip
Fire – localised/panel
Fire – extensive
Fire – turbine loss
None
Cable damage
Equipment damage

Transformer location Dropdown menu to define the position of the HV transformer

Categories
External substation
Tower basement
Nacelle

Incidents were analysed by root cause, as well as more detailed reviews of high risk scenarios:

– complete loss incidents;
– incidents with technicians on the turbine.

4 ANALYSIS OF CASES

4.1 STATISTICAL ANALYSIS OF FIRES/TURBINE/YEAR

In order to understand the risk likelihood, especially to understand whether risk was increasing or decreasing through time, an analysis of the number of fires reported per year against the average number of onshore wind turbines installed in the year, determined from industry databases, was performed.

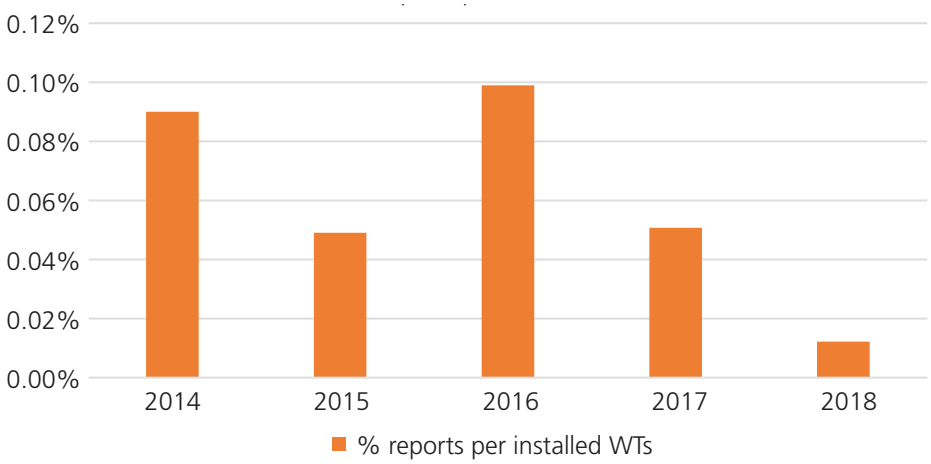

Figure 1: % reports per installed wind turbines (WT)s

4.2 ANALYSIS OF SYSTEMS/ROOT CAUSES

Of the 41 incidents reported in the five year period, each was plotted on a chart (fig 2) showing cause categorisation against effect. Known and apparent clusters were identified:

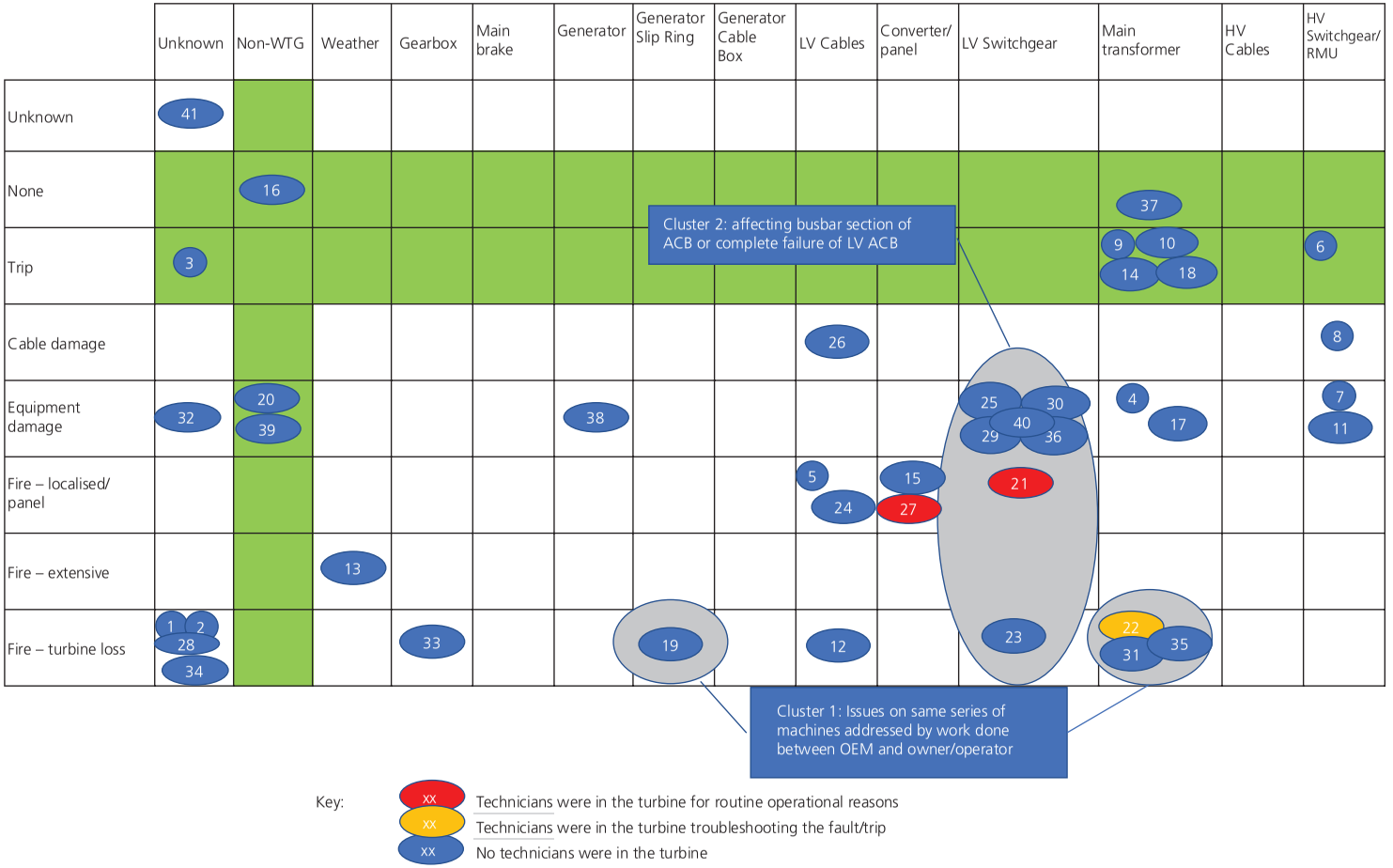

Figure 2: Summary chart of incident causation and effects

16 incidents were not included in the final analysis for the following reasons:

– Three incidents were not related to the wind turbines, but were associated with grid or switchgear located within the wind farm substation.
– Seven incidents were considered by electrical engineers to be the correct operation of the protection systems following a component failure or malfunction, and were not events which we consider could have progressed to a fire.
– One report was so vague in terms of both incident description and potential to evaluate possible consequences that it could not be pursued further.
– Five incidents are unknown to SafetyOn members through direct or indirect involvement.

The opinion of the SafetyOn TAC is that a number of the events should not have been reported under RIDDOR/ESQCR and development of guidance supported by examples would benefit industry.

Of the remaining 25 cases, two clusters became apparent.

– One related to transformer fires leading to complete turbines loss and consisted of three cases, with an additional case on the same turbine type being related to the generator. Actions taken to eliminate the causes of these fires by implementation of design changes has already been documented and presented to the HSE and SafetyOn TAC by SPR/SGRE.
– The second appears to relate to LV switch/LV busbar failures, where there have been 7 failures with similar descriptions. Each involved a release of energy which damaged the busbar unit.

This leaves 14 cases where equipment damage of some sort was caused, a localised fire occurred or a significant fire occurred resulting in a complete loss of the turbine. These were spread across 7 of the defined 'systems':

Weather (lightning)	1 case
Mechanical (gearbox, brake, bearings)	1 case
Generator	1 case
LV cables	4 cases
Convertor/main panel	2 cases
LV/HV transformer	2 cases
HV switchgear/RMU	3 cases

Other than in the clusters identified above, there was insufficient evidence of similarity between cases to consider linking multiple incidents through cause.

4.3 ANALYSIS OF TOTAL LOSS CASES

There have been 11 total turbine loss cases, which are the cases which carry the most significant risk to personnel working in and around the wind turbines. In addition, the removal and replacement of a damaged turbine introduces unfamiliar risks.

In all 11 cases, the turbine faulted while in operational (unmanned) mode. In one case, the fire was subsequently discovered by personnel investigating the reported fault.

Four of these cases (all in 2016–2018) were due to specific design faults on one range of wind turbines. These design faults have been addressed, and retrofits are in the course of application to the fleet of the largest operator of these turbines.

Other than the cluster mentioned above, the root causes of turbine losses are not associated with the position of the HV equipment, except one, which would not have occurred if the HV equipment had been in the nacelle.

4.4 ANALYSIS OF INCIDENTS WHERE THE TURBINE WAS MANNED

The second high risk scenario is that which puts personnel working in wind turbines at risk.

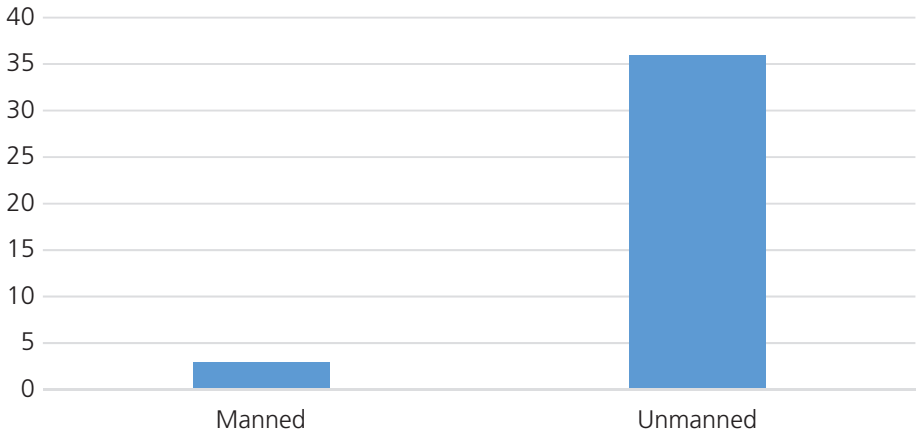

Figure 3: Analysis of whether turbines were manned at the time of reported incidents

There have been two cases where the turbine was manned at the time of an incident happening. In both cases, technicians were within the wind turbine carrying out repairs following failures of LV components during operation.

One further case involved a nacelle mounted transformer failure (part of the cluster) which resulted in technicians who were fault finding entering a nacelle, identifying that a fire was smouldering and left the turbine.

4.5 ANALYSIS OF EFFECT OF LOCATION OF HV TRANSFORMER

As determined above, all incidents involving the HV equipment have occurred during operation of the wind turbine, and therefore unmanned. For events during unmanned turbine operation, there is no direct risk to personnel, and the position of the HV equipment is immaterial.

However, for incidents that result in turbine loss, additional hazards to staff are introduced during the making safe, investigation, dismantling and rebuilding operations.

Of the seven total loss events for which data is available, four relate to components which cannot be externalised (gearbox, generator, LV cables, LV CB), with three relating to transformer fires, all of which have been addressed through the design changes already implemented by the owner/operator in conjunction with the OEM.

There was one significant release of energy recorded from a transformer located in the base of a tower, which, if sited externally to the turbine, would not have been contained by the substation to the extent that it was by the turbine tower, potentially resulting in debris and fire risk to the surrounding area.

4.6 ANALYSIS BY AGE OF TURBINE (TAKEN FROM GRID CONNECTION DATE)

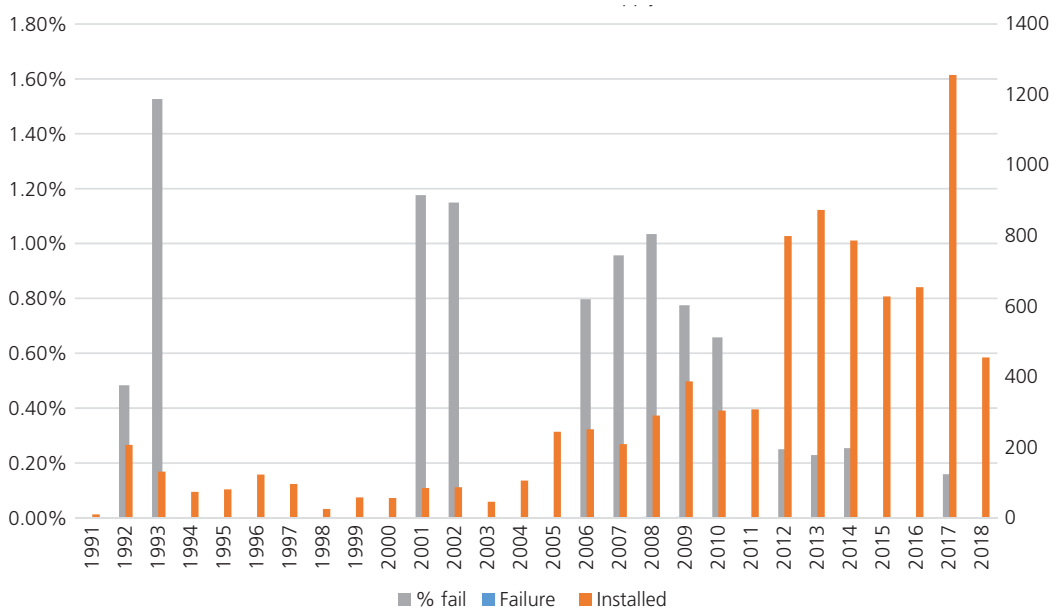

Figure 4: Failure likelihood based on supply date

In the figure above, the gold bars show the number of turbines installed in each year (from industry data). The grey bars show the percentage of turbines which appear on the RIDDOR/ ESQCR reports between 2014 and mid-2019. There are three data points excluded as the Health and Safety Executive could not identify the site concerned from the report text.

It can be seen that a turbine installed in 2010 or before has a much higher likelihood of suffering a fire related incident which is reported under RIDDOR/ESQCR, than a more modern wind turbine installed since 2011. This data supports the hypothesis that many of the technologies within older wind turbines have been improved over the years and that fire risks are continually reducing.

5 CONCLUSION

In the last five years in the UK, a significant cluster of reported incidents which have resulted in the complete loss of a wind turbine, are associated with cast resin transformer installed in one specific product range. The root causes of these incidents have been addressed through design change and a retrofit programme.

Significant fires which lead to major damage have all occurred during unmanned turbine operation therefore, there was no direct risk to personnel. Other than the significant cluster already identified and addressed, there are a range of root causes, none of which are associated with HV equipment and therefore the risk to technicians is unaffected by the position of HV transformers and HV switchgear.

Technicians have been found to be most at risk during LV switching and re-energisation following repairs. Mitigation through safe positioning should be taken into account during these operations. Where this is not possible PPE rated to withstand arc-faults should be utilised.

The data available within the industry is fragmented and difficult to surface, even with the major industry organisations involved. This has resulted in 17 % of the RIDDOR/ESQCR reports remaining unexplained within this analysis. A further 20 % of reports are related to the correct operation of protection systems without risk to personnel and equipment.

There is little evidence within the data to demonstrate significant benefits from external siting of transformers, especially now that oil filled transformers are industry legacy. The fire risk from modern dry-type and liquid-immersed (e.g. MIDEL) transformers is significantly reduced compared with the older mineral oil filled transformers. The data supports the premise that improvements in wind turbine technology are continually reducing the risk of fire.

6 RECOMMENDATIONS

Findings from this report should be compiled and shared within the industry. Learnings from the cluster of LV switch/LV busbar unit failures should be shared in the same way that it has been for the transformer delta bar issue.

The mechanisms by which this report has been created should be continued by SafetyOn using internal reporting to maintain a running, in-depth analysis of the risk of fires in wind turbines. It is believed that this will augment the data available via authority reporting with a greater level of detail on root causes of fire in wind turbines.

A recommendation is that clear guidance be developed within the industry on what should and what should not be reported under RIDDOR/ESQCR.

In light of the data presented in this report, the HSE should be requested by SafetyOn to review the letter requiring transformers to be placed externally to the wind turbine.

ANNEX A
GLOSSARY OF ACRONYMS AND ABBREVIATIONS

A.1 ACRONYMS AND ABBREVIATIONS

ESQCR	Electricity safety, quality and continuity regulations
HSE	Health and Safety Executive
HV	high voltage
LV	low voltage
OEM	original equipment manufacturer
PPE	personal protective equipment
RIDDOR	Reporting of injuries, diseases and dangerous occurrences regulations
RMU	ring main unit
WT	wind turbine
TAC	technical advisory committee

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