SIMPLIFIED HIGH WINDS ASSESSMENTS

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ABSTRACT

High winds risk can be a significant contributor to overall plant risk. To confer this hazard the appropriate consideration it deserves while at the same time reducing the associated effort, a simplified method for assessing high winds risk is presented, addressing several aspects of the assessment. Furthermore, analysis refinement of certain simplified elements is also presented. In this regard, the technical background of two software tools useful in completing a simplified high winds analysis is described: the High Winds Frequency Calculator (HWFC), which queries a database of tornado events and automatically performs a standardized calculation of tornado hazard frequency and the Tornado Missile Strike Calculator (TMSC) which assesses the probability that a wind-borne missile will impact a particular SSC, given a wind event occurs. These tools are important in completing a simplified high winds assessment as they greatly reduce the time associated with the frequency and missile analyses.

1. Introduction

The assessment of plant risk induced by high winds is a topic which is receiving increased attention in the nuclear power industry. The area of high winds risk assessment covers all types of wind hazards, including tornadoes, "straight winds" from thunderstorms or hurricanes, and special winds caused by unique geographical features of the site. The phenomenon of high winds is such that all sites are affected to some extent; and for certain sites, high winds risk can be a significant contributor to the overall plant risk. In this context, it is important to give this hazard the appropriate consideration while at the same time reducing costs to help deliver the nuclear promise. This paper presents a simplified method for performing a screening-level assessment of high winds risk. The method addresses several aspects of the assessment: walkdown, hazard frequency assessment, fragility assessment, and plant response model. Simplifications of each of these elements are presented, the goal of which is to develop a quantitative screening assessment. If the assessment does not support the conclusion that the high winds hazard can be screened out using a set of conservative assumptions (i.e., the quantitative CDF value developed is above the screening threshold), the assessment can be directly used as "robustly conservative" estimate of facility risk due to high winds and/or provide many of the key elements for the construction of a realistic High Winds Probabilistic Safety Assessment (PSA).

Considerations for performing a site walkdown, such as how to identify typical wind-borne missiles and exposed SSCs, are established. Methods for determining the wind hazard frequency using regional or national wind databases and extreme value analysis are outlined. Then, simplified fragility models can be created for potentially significant contributors to risk. Next, a simplified plant response analysis is described. The combination of these elements allows for the conservative estimation of a plant's high winds risk. Finally, considerations for iteratively refining the preceding analyses are summarized. In the second part of the paper, the technical background of two software tools useful in completing a high winds analysis is described.

The first software tool is used to query a database of tornado events and automatically perform a standardized calculation of tornado hazard frequency. This paper will discuss the adjustments made to the data by the software to account for variation in tornado characteristics and reporting. The second software tool is used to assess the probability that a wind-borne missile will impact a particular SSC, given a wind event occurs. Wind-borne missiles are one failure mode which must be considered in the fragility assessment and for which few tools are available. The software tool described in this paper uses a stochastic method to assign externally-calculated trajectories to potential missiles, allowing the missile transport model to be simplified. The missile strike software also uses a novel method to simulate the path of the tornado as it progresses through the site. This tornado path simulation is site-specific and is based on historic distributions of tornado travel. These tools are important in completing a simplified high winds assessment as they greatly reduce the time associated with the frequency and missile analyses.

2. Simplified High Winds Evaluation

A simplified method for assessing high winds risk is presented which addresses several aspects of the assessment: target list, walkdown, hazard frequency assessment, fragility assessment, and plant response model.

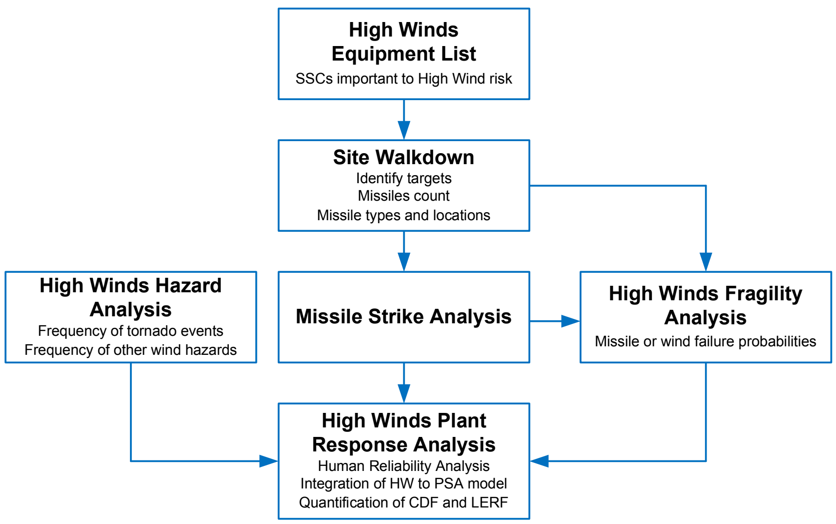

Figure 1 – Elements High Winds Evaluation

2.1. High Winds Equipment List

A target list of all structures, systems and components (SSCs) important to high winds risk needs to be identified. This list, known as High Winds Equipment List (HWEL), should include all SSCs the function of which could be compromised directly or indirectly by high wind and tornado events. The list is created by starting with SSCs included in the internal events PSA model and further additions to this list should include:

- any exposed passive structures that are required for operation of risk-significant SSCs (e.g. diesel generator exhaust vents, support system piping, etc.),
- below-ground, risk-significant passive structures (underground pipes/tanks) that may be impacted by missile impact or collapse of structures, and
- SSCs that protect or house HW risk-significant components (e.g. buildings, doors, missile shields).

Hence, SSCs not originally identified for the internal events PSA may need to be added for high winds risk assessment given the impact their failure could have on other SSCs required to maintain the plant in a safe shutdown condition. The HWEL must consider the entire component envelope. Common additions to the HWEL SSCs which are primarily inside robust structures but have portions which are exposed to the wind – for example, the diesel generator exhaust stacks. Although the diesel generator itself may be inside a robust structure, it could still be failed by the wind impact on the exposed portion. Diesel generator exhaust stacks are a well-known example, but the same considerations must apply for other components.

2.2. Site Walkdown

The performance of a site walkdown is a key element in the risk assessment and in the mitigation process of high winds. Walkdowns are intended to confirm HWEL previously defined and to assess the number, types and locations of potential wind-borne missiles as well as to include the identification of missile restraints and building framework and contents.

Most missiles generally travel less than 1000 ft./304.8 m from their initial location. This statement is supported by simulations of missile kinematics (Ref. [1]) and empirical studies of tornado damage (Ref. [2]). Moreover, for most plant sites designed and maintained in accordance with current industry practice, missile-induced failures are expected to be a relatively a minor contributor to risk, especially in simplified bounding assessment. Therefore, site walkdowns can be simplified by defining two radii at which the level of detail required for missiles varies. In the initial (screening level) assessment the analyst should concentrate on missiles located inside the area demarked by a 1000 ft./304.8 m radius from risk-significant SSCs, as shown in Figure 2. The missile count outside these areas can be established by viewing satellite imagery, which allows for a high-level estimation of missile numbers and types on less relevant areas.

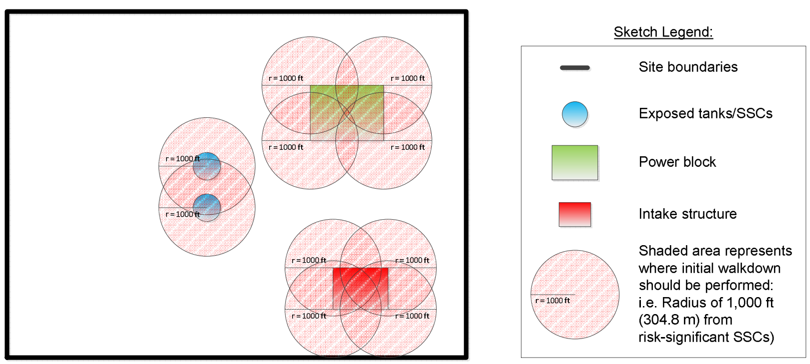

Figure 2 – Example of simplified walkdown area

During walkdowns, building design capabilities (including building sheathing) can be confirmed and plant vulnerabilities can be identified, such as weak sheathing attachments, exposed or poorly situated critical cables, motor controllers or support systems, etc. The identification of existing vulnerabilities provides an opportunity to upgrade the deficiencies, as well as, to analyse their impact. Potential site-specific low wind speed vulnerabilities are important in defining the lowest wind speeds which need to be considered in a high winds assessment. Note that the priority should be to remedy any identified deficiencies, as modelling them requires significant additional detail. Thereby, the utility reduces not only the associated high winds risk but also the effort required to develop a High Winds PSA.

2.3. High Winds Hazard Analysis

Tornadoes as well as very high speed straight winds (e.g. severe thunderstorms) may be applicable to almost all sites in some extent: these events may occur very infrequently in certain locations but they are still possible. Special winds and hurricane winds may be screened out for certain sites based on location. The simplified wind hazard frequency must be established for all of the wind hazards which are applicable to the site. This frequency can be calculated by performing extreme value analysis on data extracted from regional or national wind databases.

The high winds hazard frequency curves require the identification of site applicable wind types, which may include:

- Tornadoes,
- Straight winds, including thunderstorms, extra-tropical winds, hurricanes and tropical cyclones,
- Special winds (site specific due to geological characteristics).

2.3.1. Tornado Hazard Frequency

The tornado hazard analysis described follows the guidance of NUREG/CR-4461 (Ref. [3]).

Data Collection

The methodology employed uses the total area and length covered by tornadoes. Therefore, the required input information includes starting location coordinates, ending location coordinates, tornado intensity, segment length, and segment width. The data set to be used in this analysis can be extracted a national or international weather database. In the US, the data used comes from the storm events database published by the National Oceanic and Atmospheric Administration (NOAA) (Ref. [4]).

The Haversine formula (Equation 1, Ref. [5]) is used to calculate the distance between the site's coordinates and both the starting and ending coordinates of each tornado recorded in the database. Tornado segments the starting or ending coordinates of which are within a specified distance from the site (a regional radius or a "box" of 2-degrees latitude and longitude, depending on the method used) are retained for the site-specific tornado hazard analysis.

$$D = 2 * r_{Earth} * \sin^{-1}\left(\sqrt{\sin\left(\frac{\delta_2 - \delta_1}{2}\right)^2 + \cos\delta_1 * \cos\delta_2 * \sin\left(\frac{\lambda_2 - \lambda_1}{2}\right)^2}\right) \quad \text{Equation 1}$$

where,

D	=	distance between two sets of coordinates
r_{Earth}	=	Earth's equatorial radius
δ_1	=	latitude of point 1 [radians]
λ_1	=	longitude of point 1 [radians]
δ_2	=	latitude of point 2 [radians]
λ_2	=	longitude of point 2 [radians]

Tornado Intensity

Once the appropriate tornado data has been selected, the next step is to develop a hazard curve relating a particular tornado intensity to its frequency of occurrence. The most common tornado intensity scales include the Fujita (F) and the Enhanced Fujita (EF) Scale, which classify tornado intensities on a scale ranging from F0/EF0 to F5/EF5.

Adjustments to Tornado Data

Adjustments to tornado data may include the adjustment due to misclassification of tornado intensity, due to unreported tornadoes, due to classification scale, due to unclassified tornadoes and due to the variation of wind speed within the impact area.

1. Misclassification of Tornado Intensity
   Tornadoes are assigned an intensity on the F-/EF-scale based on evaluations of the damage caused by the tornado, not by actual measurements of wind speed. To correct this misclassification of tornado intensity, a correction matrix can be used to redistribute the observed tornado category counts. In "A Statistically Rigorous Model for Tornado Hazard Assessment" (Ref. [6]), a correction matrix is developed by assuming the misclassification is plus or minus one F-scale category at the 95% confidence level.

2. Unreported Tornadoes
   NUREG/CR-4461 (Ref. [3]) showed that the number of F0 tornadoes for years 1950-2013 has a generally upward trend, indicating unreported F0 tornadoes. The potential impact of this trend has been evaluated by NUREG/CR-4461 (Ref. [3]), concluding that any unreported F0 tornado would have little impact on tornado strike probability for more likely events and decreases the probability for low probability events. As a result, it recommends that no adjustment be made to the data to account for unreported tornadoes.

3. Classification Scale
   Regardless of the scale they were classified under, all tornado records are recommended to be used to calculate the annual tornado strike frequencies. No adjustment to the data needs to be made to account for the switch from Fujita scale to Enhanced Fujita scale.

4. Variation of Wind Speed within the Impact Area
   Per Reference [3], theoretical considerations and empirical evidence in tornado tracks indicate that only a small fraction of the area of a tornado's footprint is impacted by the maximum wind speed in the tornado. Therefore, area and length corrections matrices are presented in NUREG/CR-4461 (Ref. [3]) that are can be used in a tornado hazard analysis. These tables which described the variation of wind speed across the tornado path are reproduced here below (Table 1 and Table 2).

Table 1: Area Variability Correction Matrix

	F0	**F1**	**F2**	**F3**	**F4**	**F5**
EF0	1.000	0.772	0.616	0.529	0.543	0.538
EF1	0	0.228	0.268	0.271	0.238	0.223
EF2	0	0	0.115	0.133	0.131	0.119
EF3	0	0	0	0.067	0.056	0.070
EF4	0	0	0	0	0.032	0.033
EF5	0	0	0	0	0	0.017

Table 2: Length Variability Correction Matrix

	F0	**F1**	**F2**	**F3**	**F4**	**F5**
EF0	1.000	0.572	0.280	0.116	0.142	0.133
EF1	0	0.428	0.352	0.245	0.158	0.102
EF2	0	0	0.368	0.318	0.278	0.189
EF3	0	0	0	0.321	0.210	0.242
EF4	0	0	0	0	0.212	0.185
EF5	0	0	0	0	0	0.149

5. Unclassified Tornadoes
   If the database contains tornado records the intensity of which has not been classified, these tornadoes could be accounted for in the calculation of the annual tornado frequency by apportioning them among the counts of classified tornadoes.

Tornado Strike Frequency Calculation
Based on Reference [3], it is assumed that tornado data (i.e., distribution of tornado length and width) fits a log-normal distribution.

The total regional area considered in the tornado hazard analysis is calculated by Equation 2.

$$A = \pi R^2 \qquad \text{Equation 2}$$

where,
$R_{tornado}$ = regional radius

To compute the total area (used for point strike probability) and total length (used for structure strike probability) covered by tornadoes in the selected region, the average segment areas and lengths are multiplied by the number of tornadoes for each category. Total regional width and length are corrected for variability using Table 1 and Table 2, respectively. To compute the annual probability of a tornado strike at the site, two common approaches are utilized. The first approach calculates the point strike probability, which treats the site as a single point without taking into account site dimensions. The point strike probability is calculated by Equation 3.

$$P_{point} = \frac{A_t}{N * A_r} \qquad \text{Equation 3}$$

where,

A_t	=	total regional area covered by tornadoes, corrected for intensity variability within the tornado area
N	=	number of years of available tornado data
A_r	=	total regional area used for establishing the tornado count

Note that use of the point strike probability as described in Equation 3 inherently assumes that tornadoes in the vicinity of the site are uniformly distributed.

For larger structures, it is necessary to account for site dimensions. In this approach, the tornado and the structure characteristic lengths are used to calculate the structure strike probability, as shown in Equation 4.

$$P_{structure} = \frac{L_{site} * L_t}{N * A_r} \qquad \text{Equation 4}$$

where,

L_{site}	=	site characteristic length
L_t	=	total regional length covered by tornadoes, corrected for intensity variability along the tornado length

The total strike probability (P_{strike}) is the sum of the point and structure strike probabilities, displayed in Equation 5.

$$P_{strike} = P_{point} + P_{structure} \qquad \text{Equation 5}$$

2.3.2. Straight Winds Hazard Frequency

A straight winds hazard frequency can be established by fitting historical maximum wind speeds for the site or region to an extreme value distribution. The relevant straight winds data needs to be collected. After its compilation, an exhaustive examination of the data needs to be performed to identify inconsistencies. To account for any observed discrepancies, a consistent approach needs to be established to treat or adjust the input data considered. Finally, a linear regression analysis can be performed to fit the data to a Type I extreme value distribution, generating the hazard curve. The annual exceedance frequency for a specific wind speed can be predicted using the Gumbel distribution, which is a special case of the generalized extreme value distribution and is commonly used for predicting extreme value frequencies for parameters such as wind speed based on annual maximum observations. In order to estimate the high winds return frequencies, the data used needs to balance a sufficient time frame for analysis and accurately represent the wind features of the site.

2.3.3. Hurricane Hazard Frequency

For sites located far from the coast (approximately 200-250 miles), hurricane hazards should be screened out. The Updated/Final Safety Analysis Report (USAR/FSAR) may have additional information which may support a justification of hurricane winds screening. Alternatively, the analyst could research historical wind speed maxima for the site and region and attempt to determine if they were related to a hurricane event. However, the effort associated with such a task may be better spent on performing a simplified hurricane winds assessment if there is doubt as to whether the hazard applies.

2.3.4. Special Winds Hazard Frequency

As a result of the meteorological complications associated with special wind regions, a site which is vulnerable to special winds cannot screen out the high winds hazards and should perform a full High Winds PSA.

2.4. High Winds Fragility Analysis

The design characteristics of safety and non-safety components and structures included in the HWEL need to be assessed in order to identify the applicable failure modes and determine their associated fragility curve. Depending on the number of exposed, risk-significant SSCs, the fragility analysis can represent a considerable effort.

In order to simplify this analysis, the HWEL can be examine and the following approach can be applied: the analyst may assume that the failure probabilities for all SSCs located within robustly designed buildings[1] remain unchanged from the calculated values used in the Internal Events PSA model. For all exposed SSCs and all SSCs housed inside buildings unprotected against high winds hazards, the analyst may assume them as initially failed for any high winds event.

2.5. High Winds Plant Response Analysis

The simplified plant response analysis described below provides a very conservative estimate of the high winds risk. The intent of the high level of conservatism is to provide confidence that the wind hazard risks are bounded.

In a preliminary Plant Response Analysis, the only initiating event considered to be induced by high wind events is a weather-related Loss of Offsite Power (LOOP) event. To further simplify the analysis, it can be assumed that the conditional probability of high wind-induced LOOP events is equal to 1.00 for all high winds events under consideration as the first cut. This conservative assumption will result in the greatest reduction in risk once refined, so the majority of the additional effort will focus on justifying lower conditional LOOP probabilities for low wind-speed events. The fragility of electrical transmission equipment is discussed briefly in Reference [7].

Regarding the Human Reliability Analysis (HRA), the analyst should examine all Human Failure Events (HFEs) that apply to High Winds PSA model and assume failed any operator action which does not occur inside robust buildings for all high winds events under consideration. Nevertheless, nominal human error probabilities can be assumed applicable for all actions occurring inside robust buildings or in the Main Control Room, remaining unchanged and using the internal events associated value.

3. Refining of the simplified High Winds Evaluation

The High Winds assessment should be the result of an iterative process, aimed at ensuring that the high winds associated risk is either realistic (i.e., reflects the as-built, as-operated plant with realistic hazard and fragility models) or that it can be successfully screened out using conservative assumptions. Effort is optimized since the results of the screening assessment can be transferred to the development of a High Winds PSA if the screening is not successful.

Certain areas such as the site walkdown, the hazard frequency calculation, and fragility models for risk-significant SSCs could be refined, obtaining a balanced value between effort, cost,

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[1] Buildings designed to meet nuclear plant seismic requirements are often considered to be relatively robust to high winds.

precision and realism. Considerations for an iterative refinement are outlined with the aim of obtaining a more realistic Core Damage Frequency (CDF) result when compared to the simplified approach presented in the preceding Section. Areas which will benefit the most from refinement are detailed below.

3.1. Site Walkdown Refinement

Walkdown input information should only be refined after the first iteration, that is to say after the first quantification of high winds CDF, allowing for focalization on significant risk contributors.

Instead of estimating the missile density in certain zones, a full missile count should now be performed: the area covered by a radius of 1500 ft./457.2 m from all potential targets needs to be assessed, which may also include site immediate surroundings. Further refinement of the missile count is required for areas surrounding the highest risk-significance targets. This allows for a more detailed determination of the number and type of potential missiles as well as restraints of missiles.

3.2. High Winds Hazard Analysis Refinement

A refinement in the Tornado Hazard and Straight Winds Hazard Frequency calculation are discussed in this Section. The use of a software tool to automate this task can significantly increase efficiency.

3.2.1. Tornado Hazard Frequency

The process of defining the tornado hazard curve can be simplified by using software to automatically query a national database of tornado records. As well, standard calculations of tornado hazard frequency according to NUREG/CR-4461 (Ref. [3]) can also be automated. The use of a software tool can significantly reduce time spent on data collection and performing and documenting the calculation.

One example of such software is the Westinghouse High Winds Frequency Calculator (HWFC) which automates this process and provides a huge improvement in efficiency. The HWFC is a program used to assess the historical tornado record around a particular location and generate the frequency of occurrence for various different types of tornadoes and straight winds in that given location. The HWFC can automatically query a national database of tornado records to return all tornado events which occurred within a user-specified radius of a geographic coordinate as well as the Total Strike Probability and the Total Exceedance Probability. Additionally, the HWFC automates the extreme value analysis performed for the straight winds assessment.

3.2.2. Straight Winds Hazard Frequency

The process of defining straight wind hazard curve requires more local data sources and uses standard methods of fitting for extreme value distributions. Various sources of wind databases can be considered, such as local weather stations in the vicinity of the site, like municipal airports, as well as from the historical data recorded by the site's meteorological tower.

3.3. High Winds Fragility Analysis Refinement

This paper discusses the refinements that can be made to the missile strike failure mode using a simplified approach. Refinements to the direct wind and delta-pressure failure modes are discussed elsewhere.

The missile strike analysis is a technically complex, but required, portion of a high winds risk assessment. Thus it is uniquely challenging to accomplish efficiently. One tool which greatly increases efficiency in this aspect is the Tornado Missile Strike Calculator (TMSC), which is described in the following paragraphs.

Wind-borne missiles are one failure mode which must be considered in the fragility assessment and for which few tools are available. Thus, the missile strike probability assessment can be performed using the Westinghouse Tornado Missile Strike Calculator (TMSC), an Excel-based, macro-driven, simple to use application that calculates the probability that a certain target will be struck by a number of different missiles given a wind event occurs. The TMSC performs a stochastic sampling of tornado direction and missile injection, trajectory and strike for user-identified targets and missiles within a user-identified coordinate (zone) system. This sampling is performed across a wind-speed interval corresponding to tornado classes EF0 through EF5 in order to give a probabilistic estimate of the fraction of tornadoes which result in strike events and the average number of strikes in a strike event (defined as a specific target being struck by at least one missile during a simulated tornado). In addition, the TMSC is also capable of analysing straight-line wind (SW) events.

The TMSC also uses a novel method to simulate the path of the tornado as it progresses through the site. This tornado path simulation is site-specific and is based on historic distributions of tornado travel. Missiles are characterized by flight parameters, “injection” restraints and initial location (exposure and position) while targets are characterized by location and dimensions.

TMSC simplifies the considerable detail required to model missile injection, transport and strike by performing missile kinematic simulations externally. The result of these external missile kinematic simulations is an expected distribution of distance and height (i.e., trajectory) for a particular missile type in a given tornado. These simulations are performed for each missile type and each tornado type under consideration. Then, the TMSC assigns a trajectory to each simulated missile based on this distribution. In addition to simplifying the resources required to run the code, this technique better accommodates the considerable uncertainties associated with missile trajectories. While most missiles can be expected to have a trajectory near that of the mean produced by the external missile kinematic simulations, use of the distribution allows for some missiles to travel much further. This is more in line with empirical observations of tornado and missile behaviour. The result of the TMSC analysis is, for each SSC, a probability of missile strike in each tornado event.

Given the less damaging wind speeds of low intensity wind events (e.g. EF0 and EF1 tornadoes), it is recommended to ignore failures due to direct wind pressure on the SCCs: only failure caused by the induced-missiles strike should be considered for these types of events. Failure probability values of exposed components and non-robust buildings can be set to the missile strike probability (i.e., conditional failure probability given missile impact is 1.00). Therefore, for the lowest wind-speed events, the SSC failure probability is determined by the TMSC (note that it is assumed that there is no failure other than the LOOP initiator due to wind effects at these wind speeds).

Further refinements of the fragility analysis (i.e., development of wind fragilities) are recommended to be performed on a third iteration only. A risk importance analysis should be carried out for the exposed SSCs. Based on the obtained values, fragilities should be investigated in more details for the highest risk importance values. The analysis should assess whether the fragility values previously assigned (i.e. failure probability of exposed SSCs and of SSCs not located inside robust buildings equal to 1.00) can be decreased. As well, simplified fragility models can be created for potentially significant contributors to risk.

3.4. High Winds Plant Response Analysis Refinement

In the simplified analysis, the conditional probability of high wind-induced LOOP events is initially set 1.00 for all high winds events. This may be true for those events at high speeds (speed higher than 125 mph) based on the extensive damage these type of events are assumed to cause. However, for wind speeds lower than 125 mph, this assumption may be overly conservative. The transmission lines fragility curve can be refined based on the expected failure wind speeds in Reference [7]. This document assessed the high wind failure likelihood for a wide range of commercial structures including typical transmission towers. Based on this assessment, it is possible to estimate fragilities of typical transmission towers. Using this data one estimates, the conditional probability of a transmission tower causing a LOOP of 1E-01 for low wind speeds and increasing to 5E-01 at 125 mph. This approach while less conservative than the assumed failure assumption is likely still conservative enough to support a screening assessment. However, this assumption is only valid for sites with relatively robust local grid and switchyard components and must be verified with a more detailed fragility analysis.

Additionally, a more detailed analysis of all identified applicable HFEs should be performed. When assessing low wind speed events, the analyst should attempt to justify the success of the most risk-significant operator actions occurring in non-robust buildings or yard areas (i.e. human actions taking place outside of robust buildings). For events inducing high wind speeds, these HFEs can be still considered as failed. Justification of their success under such severe conditions would not be credible as pathways to equipment may be blocked or dangerous, a high winds event could still be in progress, wind may still be influencing debris onsite, etc.

4. Conclusion

High Winds PSAs provide considerable insight into the ability of a plant to cope with high winds challenges. These assessments are potentially significant resource-demanding and involve the use of unique analysis tools. In this regard, a simplified High Winds Assessment allows for a focus on the most risk-significant improvements. It must be acknowledged that simplifications result in considerable reduction in scope and effort at the expense of precision and realism.

When performing a simplified assessment, the time spent on certain analyses (such as hazard frequency calculation and fragility models for risk-significant SSCs) may provide significant value for the effort. And together with a subsequent iterative approach, it may facilitate the identification of areas for further future improvement as well as the refinement of the obtained results.

Finally, automated tools, such as the Westinghouse High Winds Frequency Calculator (HWFC) and the Tornado Missile Strike Calculator (TMSC) can simplify the wind hazard and missile assessments. These tools are important for completing a simplified high winds assessment as they greatly reduce the time associated with the hazard frequency and missile analyses.

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