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On Selection Of Relevant Safety And Security Scenarios For Detailed Modelling

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Abstract

Different methods exist to develop scenarios within the safety and security domain such as the morphological scenario analysis, event tree and Delphi method. In most cases, after applying these methods, a long list of possible scenarios exists. The scenario development is in most cases only the first step where the simulations, assessments or other applications take place depending on the use case. Due to the fact that there is not enough computing power or because of the longer time to set up the simulation model, often most of these scenarios cannot be further studied. Further, vague or not existing data basis can also be a reason that limits the modelling capabilities. Motivated by the above, this paper presents an approach to select the suitable scenarios for further modelling. The authors focus on the relevant safety and security scenarios for an offshore wind cluster. Further, for these scenarios the authors also propose a list of possible criteria for the selection of possible scenarios.

Keywords: offshore wind cluster, safety, security, scenario development

1. Introduction

Defining and evaluating of scenarios is an essential part in the safety and security domain. For example, for the permitting of buildings it might be necessary to model the fire behavior. Sometimes also models are used to prove the safe evacuation. Another example is the use of simulations to show failure behavior under different load assumptions in the domain of material science. All these applications study a very specific situation with defined boundary conditions. The results of the simulation are only valid for the selected boundary conditions (e.g. weather conditions, load assumptions, used materials etc.). The initial step before simulation is the definition of the scenario where a lot of different methods such as the morphological scenario analysis (MSA), Delphi method and event tree is used to define scenarios. Usually after applying these methods a long list of possible scenarios can be complied. However, in most cases the number of simulations are limited. The reasons for this depends on the type of simulation and available hardware where the computational time can be bottleneck. It is worth to note that the time needed to set up the simulation also plays a crucial role since the degree of detail for the simulation is dependent on. *What is the mash width? How large is the building? What should be the result of the simulation?* Choice of all these factors influence the studied scenario(s). Therefore, the selection of the scenario(s) must be carried out thoughtfully. This paper presents an approach to select the suitable scenarios for further assessments like a simulation. The authors are presenting this approach for the application of developing and selecting scenarios for threat scenarios for an offshore wind clusters.

The structure of this paper is as follows. The second section describes the layout of an offshore wind cluster. The third section describes existing methods to create a scenario catalog with a special focus is on the MSA and the Delphi method. The fourth section describes the procedure of creating the first (long) list of scenarios, defining possible criteria to select the scenarios for further studies as well as the final list of scenarios. The fifth section focuses on the challenges of modelling. The last section draws a conclusion and presents an outlook.

2. Offshore Wind cluster

An offshore wind farm consists of multiple wind turbines (WT). They generate the energy by using the wind force (Hau 2014). The number of turbines in a wind farm vary starting from 12 WT to 80 WT (Ørsted, 2023). The inner grid transmits the energy to the Offshore Substation (OSS). The OSS combines and changes the voltage level of the produced energy to standard values. These infrastructures together are called the offshore wind farm (OWF). Due to the fact, that the OWFs are comparable far away from the coast, a direct connection from the OSS to the landside power grid is not efficient because the loss of energy is too high. Therefore, the energy is transformed from alternating to direct current using a high voltage direct current converter platform (HVDC). Furthermore, HVDC combines the energy of multiple OWFs (Hau 2014). The transmission capacity of the HVDC varies from 400 MW to 900 MW (Federal Ministry for Economic Affairs and Climate Action unkown). One HVDC with the coordinating OWFs is called offshore wind cluster. Figure 1 shows an exemplary layout of two offshore wind cluster. The upper cluster consists of three OWFs and the lower cluster consists of two OWFs.

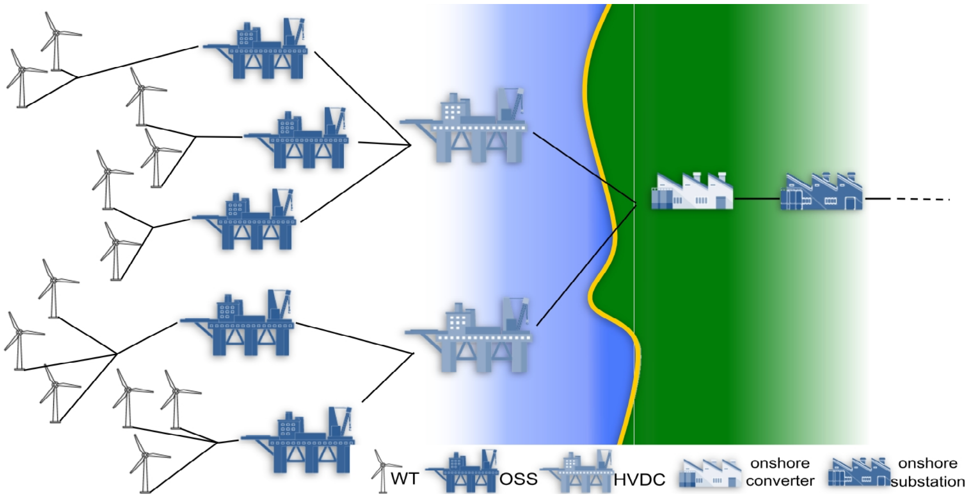

Fig. 1. Exemplary layout of two offshore cluster.

3. State of the-art scenario development

Different methods exist to define the relevant scenarios for the infrastructure protection such as MSA or Delphi method. It is always challenging to cover all scenarios while maintaining a good balance between realistic and not so realistic scenarios. In the following a few methods for scenario development is described.

3.1. Morphological scenario analysis

The MSA is often used in the security domain. The aim is to capture the threats systematically and comprehensively. A thorough MSA has following four steps:

- Determination of relevant threat factors
- List possible characteristic values
- Evaluation of consistency of characteristics
- Derivation of consistent threat scenarios (Johansen, 2018).

Depending on the context of the analysis during the determination of relevant threat factors different factors regarding intention, abilities and procedure can be defined such as motivation, expected use, available resources and knowledge. In Schneider et al. (2021) threats oriented from civilian drones are defined, for example the factors approach pattern, approach distance or the span of drones. During the second step for each factor the values of characteristics are defined. The combination of the different characteristics of the factors enables the description of the scenarios. In the work by Schneider et al. (2021) the characteristics for the approach patterns are straight line, zig-zag path (with outbreaks from the sensor area) and circling. In the third step, pairwise comparison of the characteristics takes place. A variation of this step would be the Cross-Impact Balance analysis (CIB). The aim of the CIB is to determine consistent scenarios. Difference between the CIB and the traditional MSA is that with the CIB not only a binary influence can be determined but also a multi scale evaluation is possible. Figure 2 shows the results of the influence analysis regarding the three selected factors. As a last step the systematical development based on the previous step is carried out where the inconsistent combinations are excluded. (Schneider et al. 2021).

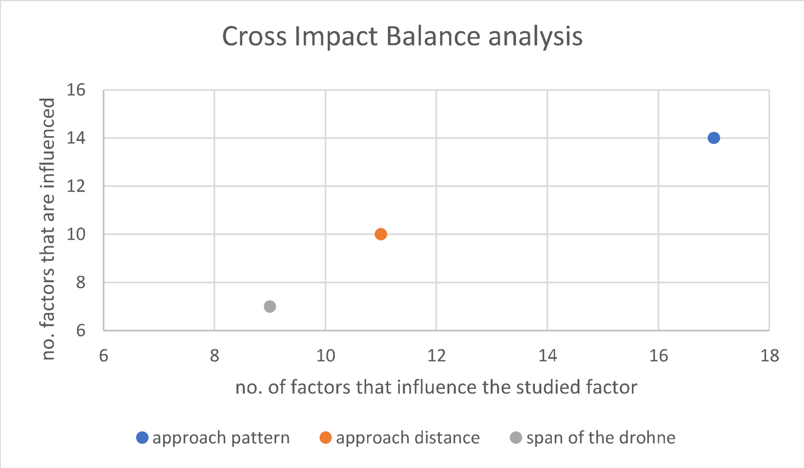

Fig. 2. Results of the Influence analysis for the selected factors according to (Schneider et al. 2021).

3.2. Delphi Method

Another option is to rely on expert knowledge. Often therefore the Delphi method is used. The aim of the Delphi method is to systematically capture expert knowledge and agree on an overall statement. There exist multiple variations of the Delphi Method. In the following the "classic Delphi" method is described. In the beginning, the topic of the Delphi-method is determined. Therefore, the focus is on factors such as the type of infrastructure or the scope of protection is defined. Furthermore, criteria that will later be evaluated by the experts are defined. In the next step, the researchers select the experts who would participate in the study. The selection should be very thoughtful because during the Delphi method one expert might influence the other experts and therefore may have a high impact on the overall statement. In the next step, the researchers develop the questionnaire. It is important to notice that, that the survey takes place anonymously. Usually the experts are either ask to evaluate a statement or prioritize a list of items. The researchers then analyze the answers of the first Delphi round and give it as a feedback to the participants where they are asked to fill in the questionnaire again. This procedure is repeated until a consensus is found. At least two rounds are necessary. (Köck-Hódi and Mayer, 2013)

3.3. Event tree

Another form of scenario collection is the event tree. This is primarily known from plant safety and is standardized in DIN 25424-1. The event tree is relatively similar to the fault tree. Fault trees belong to the top-down approaches. They start with a fault and then determine the causes of the top event. For event trees the focus is slightly different. The event tree starts with an event. The different paths are then used to show the consequences of the event. In both approaches the paths can be linked using Boolean algebra. If you follow a path of the event tree, it results in the description of the scenario. Figure 3 shows the event tree for the scenario of incorrect calibration of two measuring instruments. (Hauptmanns, 2020)

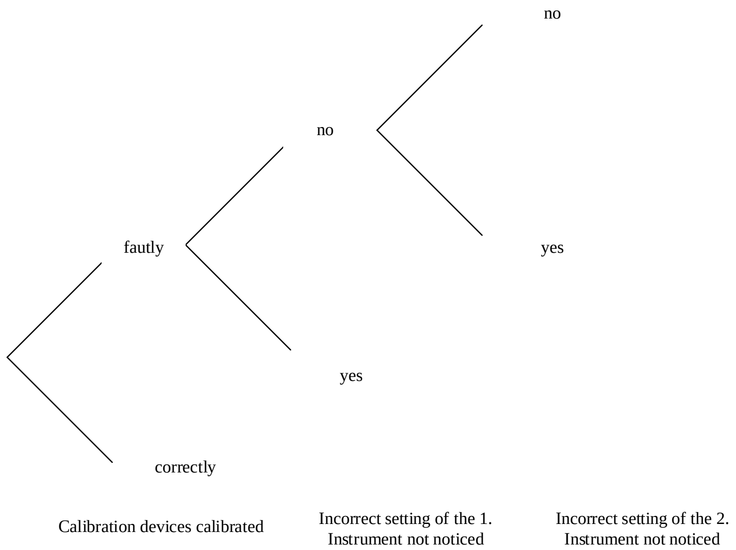

Fig. 3. Event tree for the scenario incorrect calibration of two instruments according to (Hauptmanns, 2020).

4. Selection Process

In the first step the authors performed an event tree and systematically developed multiple scenarios (see 4.1). After that authors searched for possible criteria to select the relevant scenarios for modelling (see 4.2). In the third step the authors applied the evaluation criterion to the previous first list, and selected the most relevant scenarios for the further modelling.

4.1. Initial list of scenarios

The initial list of scenarios has been developed through the variation of the event tree. The initial event is an attack of on an offshore wind cluster. The first branch of the tree is the start vector from where the threat is oriented. The possible options of start vector for an offshore wind cluster are: above water, below water, air, internal (either intentional or unintentional), land and cyber based. The second branch is then the target vector. The target vector has the same options like the start vector. The third branch is the target aim. This describes the specific infrastructure for example the export cables or the substructure of the substation. Figure 4 shows the structure of the event tree. For each target aim multiple consequences or impacts exists. The authors decided to not include them in Figure 4 because the readability of the drawing would lose. Therefore, the consequence/ impacts alongside with the duration of the attack can be seen in table 1.

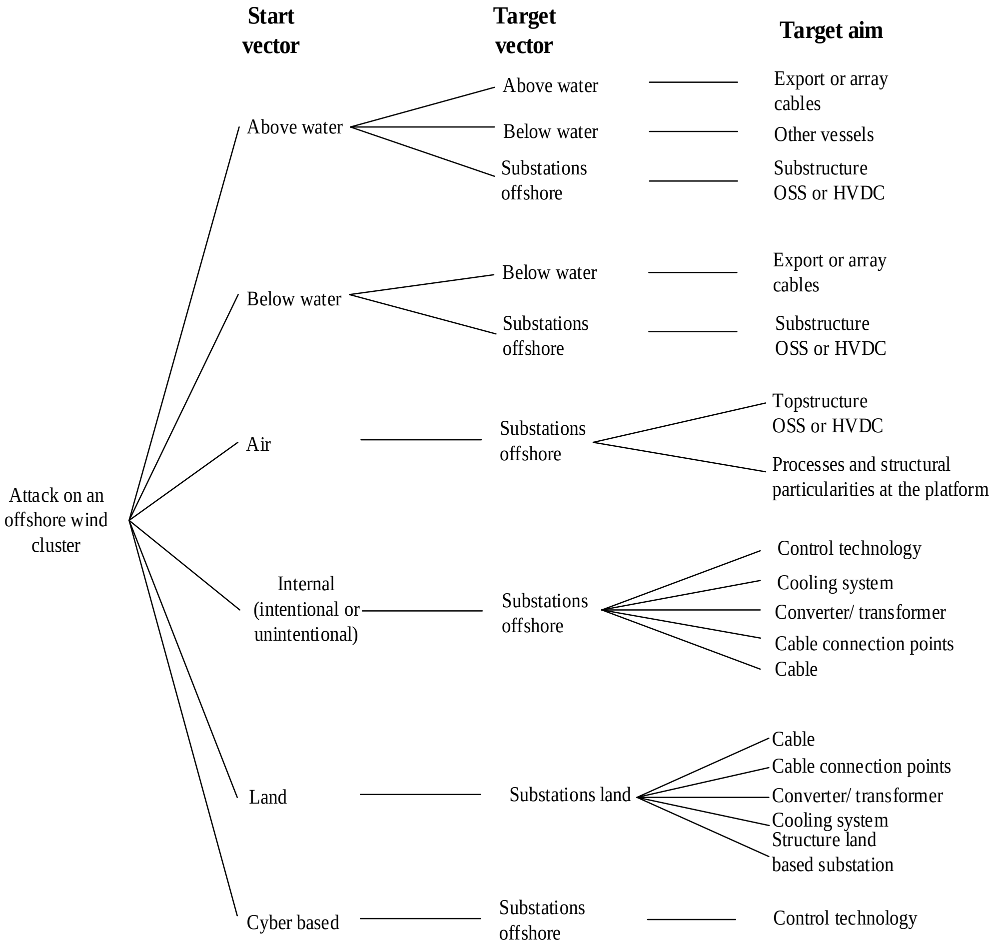

Fig. 4. Event tree regarding the offshore wind cluster.

Table 1. Extraction of the initial list of scenarios with the scenarios regarding the start vector "above water".

Start vector	Target vector	Target aim	Consequences/ Impact	Duration
Above water	Above water	Other vessels	Collision with other vessels	Until the damaged or sunk vessels are removed
			"Blocking" the way	Until obstacles are removed
			Spying from fishing vessels or recreational crafts	Until spied out design is changed or information is used against operator
	Below water	Export/ array cables	Emergency Anchorage	Until cable is replaced
			Anchor as a weapon	Until cable is replaced
	above water or air	Substations, Substructure	Collapse of platform after vessel collision (CTV or maintenance)	Until new platform is built and installed
			Mayor physical damage to substructure after vessel	Until replacement of affected parts is performed

	collision (CTV or maintenance)	
	Minor physical damage to sub structure after vessel collision (CTV or maintenance)	Until reparation of affected parts is performed
	Place for propaganda	Until propaganda is removed and if necessary counter information spread

4.2. Evaluation Criteria

Using the event tree in the previous step, a total of 42 scenarios have been developed. During this intermediate step, the aim was to determine the most relevant scenarios for further studies. Therefore, the researchers developed a list of multiple evaluation criteria. By using the method "Stimulus word analysis" this list has been developed. The Stimulus word analysis works traditionally in two rounds. For the first round, the user needs a random item. In this case it is a mug from a landlord. During the inspiration phase the user writes down all the characteristics of the item. At this stage the characteristics of the item does not need to have anything in common with the original question/ problem. An example characteristic is "red" because the color of the mug is red. During the transfer phase the previous characteristics are forced to fit to the problem itself. In this case the authors performed a second transfer phase three weeks after the initial stimulus word analysis. The results of the different phases can be seen in table 2.

To select or exclude a specific scenario, a quantifiable unit is necessary. Depending on the use case, a semi-quantification is also possible. Applications for a semi-quantification can be possible if the scenarios in the highest category is selected. On the other hand, if the top three scenarios are further studied, a quantification is necessary. In our case the limit for further scenarios is limited to 6 scenarios. The authors decided to use the unit mean time to repair (MTTR). According to the British standard "Maintenance – Maintenance Key Performance Indicators", the MTTR is calculated by dividing the total time to restore by the number of failures (BS EN 15341:2007). One reason to select the MTTR is that the MTTR is an established value, which means that numbers for different parts in the infrastructure has been published (see section 4.3). Furthermore, the MTTR also describes the output of the transfer phase 2 of the characteristic "water". The research project "Design and operation of networked energy systems" (DESYS) focuses on the energy modelling of offshore windfarms. Thereby the focus is also on the effect of fluctuating or even collapse of the energy supply either due to low wind phases or due to down times. Having this in mind the authors selected MTTR. During the repair no energy production can take place. Therefore this are the times that are most critical to the energy network.

Table 2. Possible criteria to select scenarios for further analysis.

Inspiration phase	Transfer phase I	Transfer phase II
Red	Particularly bad/ terrible	What does terrible mean? Possible: Number of people affected, time to recovery
Flat	How many people were affected by the incident?	4 walls -> Box -> Can the effects be reduced by switching off the grid, for example?
Water	Effects, location (e.g. above/under water)	Extinguish -> What is needed to restore? -> How long does it take to restore?
Cylinder	What radius does the impact have?	Which area is affected? Are there any critical consumers that are out of service? (e.g. hospitals, banks, etc.)
Porcelain	Fragile -> vulnerable areas	Are vulnerable areas affected? If so, how many? How likely is the scenario?
Handles	-	How many safety systems are there to prevent this incident?
Give away	-	Money -> cost to repair or expenses in the event of default
Alternative to coffee to go mug	-	Garbage -> Environmental damage of incident
Transport container	-	Content of mug -> vital ->Human life

4.3. Selected Scenarios

For all the previous determined scenarios (see section 4.1) the MTTR has been determined. Therefore, different literature sources have been evaluated. The six scenarios with the longest MTTR are listed in the table 3. Further, a brief description of the scenario itself along with an explanation of MTTR has also been stated. The authors limited themselves to six scenarios due to the constraints of the research project. Overall it can be said that the user of this approach should decide how many scenarios should be studied. This of course depends on the application of the modeling, the timely and financial resources as well as the used modeling type. Generally speaking the user should ask him- or herself whether more incorporate scenarios add value to the analysis. Does a new scenario add a new aspect to the analysis or is it already included in one of the other scenarios?

Table 3. Selected scenarios for further analysis.

	Scenario	Reason
1.	Cut of export cable due to anchor or fisher nets	The cut of a cable can be repaired but specialized companies are necessary. Sannino et al. stated that the MTTR for an offshore export cable varies from 720 h (summer) until 2160 h (winter). Focus: AC (Sannino et al. 2006) Gong et al. state only a best and worst case scenario. The time frames for that are in the same size range 1 to 3 month.(Gong et al. 2018) Focus is: AC DC submarine cable: 1440 h (2 month)(Cheah, 2017) 30 days for high voltage DC cable (Bresesti et al. 2007)
2.	Collapse of offshore platforms	Nordic yards present at their webpage the construction times for a few offshore HVDC converter platforms. The project with the shortest construction time 3 years and 2 months. (nordic yards) This is only the production time. But also, times to install it offshore needs to be considered. In case of a severe accident or attack, the time until the manufacture can start with the production needs also to be considered.
3.	Functional failure cooling system	Used the Oreda handbook: 12h (active repair times) (Selskapet for Industriell og Teknisk Forskning 1997)
4.	Functional failure of transformer	The MTTR amounts to 21 days/ 504 h. (Bresesti et al. 2007) 1512 h (Cheah 2017)
5.	Functional failure of converter	The MTTR amounts to 12 h. (Shafiee et al. 2015) 192 h for a converter reactor (Cheah, 2017)
6.	Loss of land-based substation	Building time around 2 years. (Tennet, 2022)

5. Conclusion and Outlook

This paper presents an approach for the selection of scenarios for further modelling. Therefore, the authors first introduced existing methods to define scenarios. Usually these methods create a long list of scenarios. In the next step, the authors developed a variety of criteria for the final selection of the scenarios. In this case, the authors used the criteria “MTTR” for the selection of the final scenarios. But this of course can also depend on the application and the purpose of the further work. If, for example, environmental protection is very important to users, other criteria must be taken into account when selecting scenarios. In this case it might be suitable to look at the possible pollution of the near by environment. The proposed approach with the criterion “MTTR” has been used to create and select safety and security relevant scenarios for offshore wind clusters.

Further work could be done regarding the assignment of different selection categories to possible study areas. The aim would be to point out which selection criteria is useful for which application. Align with this idea an investigation can be carried out to see the benefits of combining selection of factors. This study did not focus on validation of the selection criteria which can be done using Delphi method.

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