A joint approach to Safety, Security and Resilience using the Functional Resonance Analysis Method

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Motivation for this work

Power supply by wind farms is growing in Germany
→ 03/2019: 6,616 MW → 12/2020: 7,700 MW → 2030: 15,000 MW

Electricity generating units with a capacity of 420 MW and above becomes critical infrastructures and their seamless functioning should be protected.
Project

KISS – Key performance Indicator (KPI)-based monitoring of the safety and security level of offshore wind farms (OWF) in real-time
- development of the system theoretical background for the description of safety/security levels in the system OWF
- Elaboration of a practical concept to supervise safety/security in real-time
Safety, security and resilience (SSR)

Resilience

~ is considered as “the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions.


Safety aspects

~ unintended disturbances and threats 1…N in relation to diversity of safety goals

- random events
- carelessness
- inabilities

Security aspects

~ intended disturbances and threats 1…M in relation to security goals

- vandalism and attacks as purpose
- criminal and terroristic attacks as mean

flanks of vulnerability and brittleness

subject under protection

OWF

barriers, defence and mitigation means, recovery mechanism, incident management…
## Diversity of objectives of OWF stakeholders

<table>
<thead>
<tr>
<th>Stakeholder</th>
<th>Accident prevention</th>
<th>Security</th>
<th>Occupational Safety</th>
<th>Compliance</th>
<th>Environmental Protection</th>
<th>Reputation</th>
<th>Plant Safety</th>
<th>Finance</th>
<th>Supply Reliability</th>
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Interrelation between objectives

Nine general objectives (SSR goals) are derived and prioritized:

1) Accident prevention
2) Security
3) Compliance
4) Occupational safety
5) Environmental protection
6) Reputation
7) Plant safety
8) Supply reliability
9) Finance
Mapping of objectives on functions

- Five prioritized overall objectives are represented by 64 functions of an arbitrary OWF e.g. fire detection, safe helicopter, or safe information.
- The 64 function may be classified regarding their main responsibility:
  - functions to protect specific components and processes
  - functions to perform/manage the maintenance of safety
  - functions to gather safety-relevant information (status, trends, conditions)
- Resilience analysis matrix (RAM)
FRAM

Basis for the influence matrix.

Heat detection
Monte Carlo simulation

- Every function has three main properties:
  - Failure probability \( p \)
  - Time to restore/repair \( t \)
  - Influencing factor \( f \)

- Simulation over one year:
  - Every day uniform random numbers are generated.
  - Some functions fail and influence the downstream functions.
  - Some functions are restored (countdown \( c = 0 \))

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<th>Day</th>
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<th>Fire detection:</th>
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<td>( c = 0 )</td>
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Failure probabilities over one year

Function # 18
What is wrong with function # 18?
Impact of safety measures

Introducing two new measures reduces the number of work accidents per year.
Summary and outlook

Summary
• Simulation approach to propagate function failures through a FRAM model
• Conceptual identification of critical functions in infrastructures
• Quantitative evaluation method for additional safety measures

Critical review
• Safety II still needs to be implemented, performance can be degraded
• Model and risk assessment need to be validated

Outlook
• Automate re-evaluation after implementing a new measure
• Analysis of the slope of function failure probability to predict failures