Complex system for risk assessment in ESD hazardous processes with unusually high risks

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Abstract. Many types of granulated substances and liquids that are heavily used in industry may become easily inflammable when they are adequately mixed with air either in fine particle or vapour form. Many of these substances have very low conductivity which means that the particles can easily acquire electrostatic charge during transport or mixing operations, and the resulting electrostatic discharge may ignite the atmosphere leading to damage and even loss of life. The probabilities with which these events occur are hard to quantify. The authors present a case study and estimate the probability of ignition using FFTA (fuzzy fault tree analysis.) The result of the calculations is affected by several parameters, such as process temperature and humidity, which using suitable instruments can be easily observed. The authors thus propose a new approach where these parameters can be continuously monitored, and the fault tree evaluated in real time and early warning of the danger can be provided.

1. Introduction
In many industrial processes the management of electrostatic charge accumulation and discharge are very important. These include processes in which inflammable atmospheres are created when a low conductivity fluid vapour or fine particles of granular substance are created, as these can be easily ignited by the energy of the discharge, resulting in fire or explosion, possibly causing damage to apparatus and sometimes even resulting in loss of life. Such applications include the transportation and mixing of certain liquids and powders highly susceptible to ignition like flour, pharmaceutical substances or gasoline. [1] [2]

It is clear from the above that it is vitally important that the risk due to electrostatic discharges is properly managed, which in turn relies on the ability to accurately estimate risk. [3]

Charge accumulation can be modelled by the simple parallel circuit of a capacitor and a resistor being charged by a current source. Such a circuit is shown in figure 1. The capacitor in the circuit represents the capacity inherent in the system geometry, the resistance provides the relaxation if the system including both inherent and artificial grounding, while the current source provides the current caused by the separation of charges. The spark gap illustrates that once a sufficiently high voltage is accumulated, a discharge shall occur.

When designing solutions for suppressing discharges, usually lowering the grounding resistance is the method of choice.

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2. Fuzzy fault tree analysis

One of the methods widely employed in the industry for estimating the probability of damage due to electrostatic discharges is the fault tree, which relies on decomposing the top event, the probability of which we seek to determine, into certain simpler events, the probabilities of which are better known or are easier to estimate. [4]

In case of fuzzy fault tree analysis (FFTA), the probabilities of basic events are not simply numbers, but instead they are membership functions. This allows us to incorporate the uncertainty of estimates into the calculations. The resulting probability for the top event is in this case also a fuzzy membership function, which allows us to estimate the error of the result, or inversely, to determine which base probabilities need to be better estimated to decrease the uncertainty of the estimate.

In our case study we shall use triangular membership functions, of which an illustration is provided in figure 2. Throughout the calculation we shall assume that the product of two such numbers has the same form with the minimum, peak and maximum points being the respective products of the operands.

3. Case study

In the article we shall examine a prototypical process in detail. In this process a powdered substance is pneumatically transported into a container for further processing. A discharge may arise between the destination container and the end of the tube used for filling it. The container, the tube used for transportation and the destination container are all earthed. For the purposes of this study, it will be assumed that the destination container is permanently well grounded, however the source container, as it is mobile, shall be grounded by workers each time it is replaced and therefore we have to account for failures in this grounding path, which has four connections, each of which have to be intact in order to dissipate the accumulating charge. For additional safety, the worker handling the tube wears conductive clothing, socks and shoes and stands on a conductive floor.

It is clear, that while the grounding of the tube is intact, no risk of discharge is present, however should this fail, the accumulated charge has to be conducted to earth via the clothing of the worker and through the floor. This grounding path may fail due to a number of reasons, including low humidity in the plant, that causes an increased resistance on the interfaces between the tube and the clothing of the
worker, or the conductive shoe and floor; low conductivity of the transported medium and in connection to this, the low temperature of the container located outside also increase the risk of discharge, and high process temperatures provide a powder that is more easily ignited. The fault tree for the process is presented in figure 3. For this study, the probability of the presence of an inflammable atmosphere is assumed 1, and the probability of ground failures is a triangular membership function with a minimum at 1%, the peak at 2% and the maximum at 3%.

4. On-line monitoring
The parameters that the probability of the top event depends on can be easily measured and monitored, which allows us to evaluate the fault tree at each time instant. Let us assume that the parameters vary according to the diagrams presented in figure 4.

For evaluating the fault tree, we obtain parameter values for each instant by using an average of past values with exponentially decreasing weights, with 0.5 weight assigned to the values measured 15 minutes ago. Likewise, the standard deviation of the values is computed, and for the resulting probabilities a triangular membership function is used extending one standard deviation in each direction from the average. The computation results in the top event probabilities shown in figure 5.

Figure 3. The fault tree for the process.

Figure 4. Variation of process parameters.
For comparison, a computation using the averages and standard deviations for the entire period was carried out, which results in an estimate of (0.01, 0.06, 0.112). It can be readily seen that the estimate using the global statistics is in good agreement with the results obtained by using time-dependent data, however the uncertainty of the former is much higher.

The time-dependent analysis can be used to observe at which stage of the process the significant risk arises, and this can aid in providing optimal measures for the reduction of the risk associated with the process.

![Figure 5. Probability of the top event. Minimum, peak and maximum of membership function shown.](image)

### 5. Conclusion

The authors propose and demonstrate that when the input parameters of fuzzy fault trees are in close relationship with physical parameters whose time dependent variations are easily measured, additional information can be obtained by evaluating the fault tree in continuous time. This may be done based on logged data, in order to optimize the process in a targeted manner, focusing on operations where the probability of damage is highest; and possibly also in real time, to alert operating personnel to parameter constellations that carry unusually high risks.

### 6. References

[1] Berta I 2005 Static Control *Journal of Electrostatics*. 67:(2-3) pp. 297-300

[2] M. Glor 2007 Ignition risks from static electricity – problem solved? *Journal of Physics: Conference Series* 142 pp. 1-6

[3] Kiss I 2009 Increasing the reliability of risk assessment for systems endangered by electrostatic discharges. *Journal of Electrostatics* 67:(2-3) pp. 297-300

[4] Kiss I, Szedenik N, Berta I 2009 Electrostatic hazard and protection: expert system for fuel delivery modules *Journal of Electrostatics* 63:(6-10) pp. 495-499