Fire and Gas Mapping: Comparative Impact of Different Standards

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Fire and gas detection mapping plays an important role in determining the optimum location of detectors, however, there is limited formal guidance on the approach and methodology used for conducting these studies. More recently several guidance documents have been written to assist in determining the quantity and location of fire and gas detectors required.

Understanding the impact that different standards and guidance have on the overall fire and gas system is of interest to the industry. Additionally, the level of subjective input and assumptions required for the different guidance documents may affect the replicability and comparability of the results.

This paper presents the results of a review using different approaches within the available standards and guidance. To enable comparisons of the different approaches, a fire detection mapping assessment has been performed using each of the approaches and applied to a representative installation. The assessment has been performed using the fire and gas mapping software, DELOS, and the results have been evaluated by comparison of the flame detector coverage and the protection provided to the installation in terms of both the number of flame detectors required and the resulting flame detector layouts produced.

Keywords: 3D, Fire & Gas Mapping, Fire & Gas System, DELOS, Fire Detection, Flame Detection

Introduction

Early detection and intervention of process loss of containment, a release, or an early onset of fire in a process plant is a critical factor in process safety management. A fire and gas (F&G) detection system plays an important role in ensuring this early detection and any control action to reduce the likely consequence severity resulting from such an event. F&G mapping assessments are used to ensure optimum placement of the detectors for early detection.

Historically, the F&G mapping approach used in the industry has been dictated by major operators such as BP (2009), Shell (2018) and Total (2011) who have often developed their technical guidance for F&G detection. In the early 1990s, the UK's Health & Safety Executive (HSE) (1993) carried out research into flammable gas detection, which initiated an industry-wide push for both more detailed analysis of where detectors should be placed as well as assessments of the effectiveness of the detector location and coverage.

More recently several international standards and guidance documents have been written to assist in determining the placement and quantity of F&G detectors for optimum hazard area coverage. These include BS60080 (2020); a revised edition of ISA-TR84.00.07 (2018) and Energy Institute Guidance (2020). Understanding the impact that different standards and guidance have on the overall F&G system is of interest to the industry. Additionally, the level of subjective input and assumptions required for the different guidance documents may affect the replicability and comparability of the results.

Principle of Fire and Gas Mapping

AF&G mapping assessment is used to determine the optimum placement of F&G detectors within an identified zone of a facility. The assessment aims to optimise the detector configuration to maximise coverage of the protected equipment and areas whilst providing redundancy to guard against false trips and detector faults as well as reducing installation and maintenance costs. The assessment addresses the location and coverage of the detectors within the identified facility area to ensure that fires, or gas releases would be detected early for necessary intervention and action. These need to align with the end user performance criteria, standards, and industry best practices.

An appropriately designed F&G detection system enables mitigation of hazardous conditions such as fire or loss of containment by performing three basic functions:

- Detecting the hazard;
- Alerting personnel;
- Initiating appropriate mitigating/control action(s).

F&G detector mapping studies provide an objective analysis of detector layouts to support the design process and optimise the number and placement of detectors needed to meet performance requirements.

3D mapping software is routinely used to afford quick, efficient, and accurate analysis of the detector placement considering the hazards being protected against, the facility layout, obstructions, and other environmental conditions. The software often allows the user to:

- Perform area grading and determine volume extents in the case of fire detection;
- Use a 3D layout for detector analysis;
- Calculate gas detector (both point and line of sight detectors) coverage;
- Calculate heat and flame detector coverage with regards to the respective hazard areas;

- Account for obstructions in a 3D environment;
- Allow multiple coverage targets to be specified within an area; and
- Produce outputs including coverage statistics, area grading and detector coverage maps in both 3D, and 2D slices.

The assessment generates a coverage map and coverage statistics taking into account the number and location of the detectors and the performance criteria, i.e., whether alarm and control actions, 1ooN and 2ooN and variable reference fire size / radiant heat output (RHO) are required for the area to be protected. If coverage criteria are not met, the detector layout is tuned to ensure those minimum spatial coverage goals are met. For fire detection assessments, there is often no consideration of the likelihood of a fire starting, with the reference fire treated equally likely at each position in the detection zone.

The Need for Standardisation

The demand for F&G mapping assessments has been increasing, however, the lack of national or international standards or guides means that the outcome of these assessments can vary widely. In most cases, the assessment is either conducted with reference to company guidance where one exists or an ad-hoc agreement between the consultant and client. Assessing and comparing these mapping results is often difficult. Additionally, the availability of computers with fast processing power and the advancement in software development makes the deployment of 3D mapping software commonplace. This software allows for performance-based F&G mapping to become the more common approach. However, this increases the inconsistencies in the design with very limited independent third-party review of the software output. It is common for a client who has engaged different F&G mapping consultants to have widely different results recommending a significantly different number of detectors for a similar plant area, all other factors being equal.

Industry players saw the need for having an international standard or guidelines that would aim to harmonise all the disparate methodologies and come up with a consistent and comparable approach that ensures similar levels of safety are provided across the industry.

Development of International Standards

In 2003, the first edition of IEC 61511 (Standard for Functional Safety in the Process Industry), was released and was adopted by ANSI/ISA in 2004 as ISA 84.00.01. This was deemed the first international standard to include F&G system assessment. However, this standard is performance-based and does not directly address how the F&G mapping and assessment is conducted. ISA then set up a committee to produce practical guidance on the application of the standard to F&G system assessment. The first edition of the guidance ISA-TR84.00.07 was published in 2010. This was considered the first international guidance that aimed to codify best practices in F&G system analysis and mapping, even though it was geared more towards instrumentation engineering.

ISA-TR84.00.07 (ISA, 2018) was the main international standard for a decade until 2020 when both British Standard BS 60080 (BSI, 2020) and the Energy Institute (EI) (EI, 2020) guides were released. The three standards have a similar approach generally; however, they have differences in some areas, driven by several factors including the target audience, scope, etc.

The major driver behind these standards and guidance is to address design inconsistency in relation to F&G mapping and to allow for the appropriate application of performance-based design in conducting F&G system analysis.

Perceived Differences in the Standards Approach

Of the three standards and guidance, the EI guidance is mostly applicable for design at the concept stage as it contains little design guidance for carrying out detailed prescriptive or performance-based F&G mapping studies. It references ISA-TR 84 where specific details can be obtained.

The BS 60080 and the ISA-TR84 both offer a detailed guide on what is expected for an F&G system assessment and therefore have been considered here in detail.

Although the general approach is similar, the standards and guides have differences in some areas such as in determining graded/hazard areas and coverage factors. For example, for flame detectors, both ISA-TR84 and BS60080 use a risk assessment approach to determine the risk areas, however, ISA-TR84 uses an additional semi-quantitative hazard ranking method resulting in an adjusted risk area. Also, while BS 60080 de-emphasises the use of fixed coverage factors as a marker for the performance target, ISA-TR84 implies reliance on a coverage factor as part of the overall F&G system effectiveness determination. Other areas with potential differences include the determination of detector sensitivity and the target RHO.

Case Study Application – Flame Detection

In order to investigate some of the differences in the approach and potential outcomes of the ISA TR84 and BS 60080, a case study application of the two standards has been carried out on the deck of a representative offshore installation, shown in

Figure 1. The case study is limited to flame detection mapping and aims to show whether applying design guidance from the different documents could result in a similar level of detector requirement and protection, or widely different outcomes.

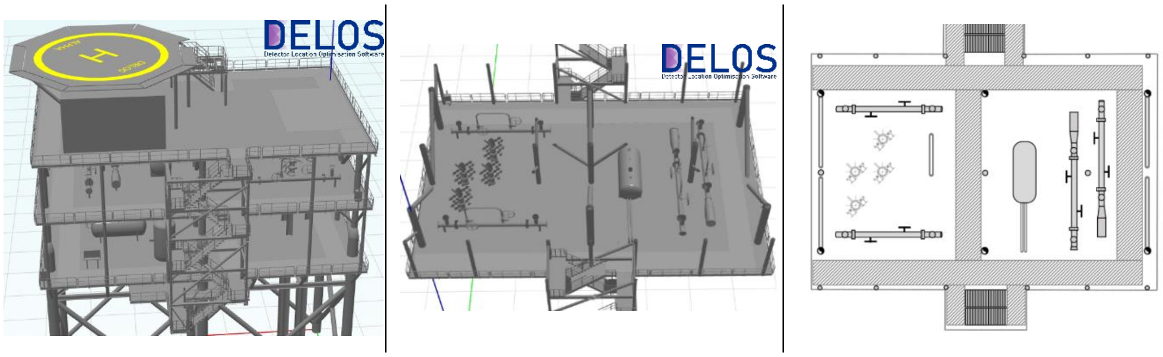

Figure 1: Case Study Platform and Deck Level Showing the 3D Overview (left & middle) and 2D Plot Plan (right)

DELOS, a 3D F&G mapping software developed by ESR Technology has been used to carry out the assessment as it provides all features required for the analysis carried out in this paper. The software uses the 3D model of the plant and calculates each detector's 'view' and coverage in 3D. DELOS can be used to assess flammable gas detection, toxic gas detection and flame detection. DELOS operates in full 3D, is capable of loading complex CAD models and has in-built detection logic that determines the optimum detector layouts, including the use of a genetic algorithm for the automatic optimisation process. Results can be presented in 3D format, or 2D slices at a reference height, whichever provides the most insight.

The detector mapping is presented depicting the detector's field of view, called a footprint. The footprint for the flame detector, for example, depends on the performance criteria adopted, including considerations such as whether 1ooN or 2ooN is required and whether a fixed or variable target fire size is required for alarm and control actions. Figure 2 gives examples of footprints and their description. The left diagram is the footprint when a different target fire size is required for alarm and control action while the diagram on the right is the footprint when the same target fire size is required for both alarm and control action. Generally, for confirmed fire resulting in any control action, two or more detectors' fields of view need to overlap.

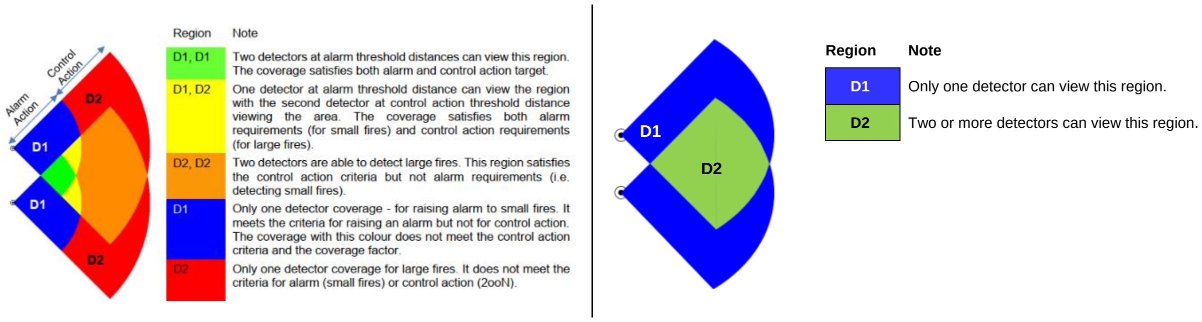

Figure 2: Detector Footprint

Once DELOS has been used to assess the coverage provided by the proposed fire detectors, the results are analysed to see if the performance criteria are met. Where the detectors provide adequate coverage, no optimisation or adjustment is necessary. If these criteria are not met, the detector layout is optimised by changing the location or orientation of the detectors, with additional detectors being proposed if required. Figure 3 shows the DELOS software window.

To assess the differences in the various approaches and the potential outcomes, the two standards have been reviewed, coming up with design options as shown in Table 1. EI guidance is excluded as it only offers high level provisions and does not provide any detailed design guidance to afford comparison.

The guidance and recommendations provided within the two Standards – BS 60080 and ISA-TR84- have a number of nuances implying different users could come up with different proposals depending on the user's judgement, experience, and background. Whilst this offers flexibility in the design, the approach creates difficulty in achieving design consistency and makes comparative analysis difficult. For this assessment, five cases have been developed, three from ISA-TR84 and two from BS 60080, based on the example approaches provided in the documents and some of the main suggested factors highlighted in the documents. The features used for the mapping in each case are shown in Table 1. Note that the combination of factors considered in developing the options are those with a likely high impact on the detection requirement.

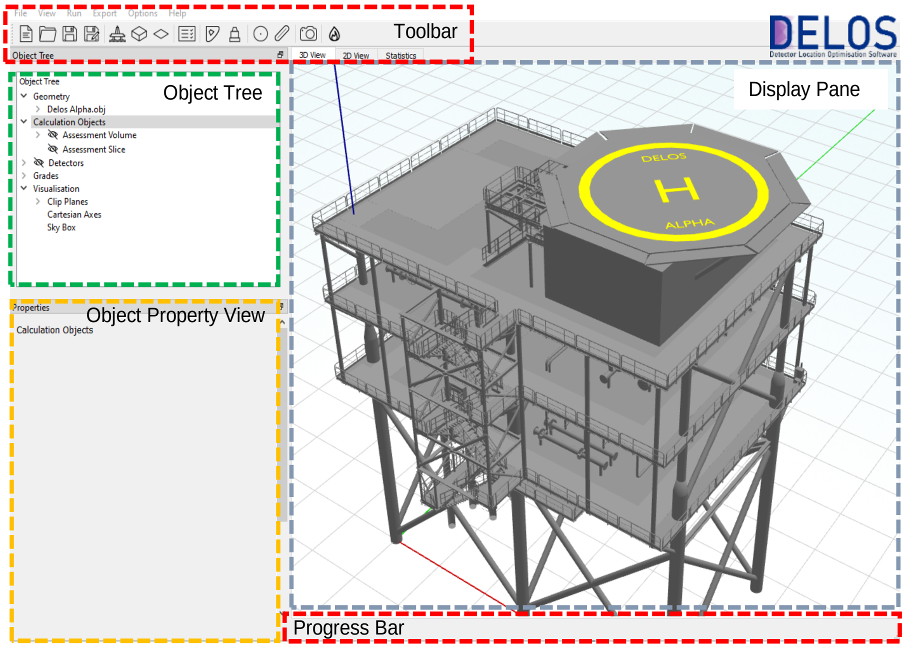

Figure 3: DELOS Software Window

Table 1: Case Study Features

Features Assessed	Case				
	ISA-1	ISA-2	ISA-3	BS-1	BS-2
Performance target identification and developing hazard / graded area	☑	☑	☑	☑	☑
1ooN for alarm and 2ooN for control action	☑	☑	☑	☑	☑
Applying minimum boundary area/volume	☐	☑	☑	☑	☑
Using manufacturers claimed (ideal) viewing distance	☑	☑	☐	☑	☐
Using reduced (effective) viewing distance	☐	☐	☑	☐	☑
Using the same target flame size (RHO) for alarm and control action	☑	☑	☑	☐	☐
Using different target flame sizes (RHO) for alarm and control action	☐	☐	☐	☑	☑

Methodology

The methodology of the study follows the stages shown in Figure 4 and described in the following steps:

- Receive and review the facility data input from the end user including 3D model, plot plans, fluid characteristics, heat and material balances (HMB), piping and instrumentation diagrams (P&ID), previous safety studies, specific client requirements, company standards and guidance and environmental conditions;
- Carry out risk and hazard assessments to identify areas where protection would be required and the risk scenarios within such areas;
- Determine the hazard/graded areas which delineate the protection area;
- For a facility with a preliminary or outline assessment conducted, review the preliminary F&G detection systems provided;
- Identify the F&G detection arrangements required for the equipment in terms of detector type, location, orientation, and elevation;
- Using the 3D software, assess the proposed detector arrangements, considering the coverage requirements; and
- Optimise the detector layout by changing the position of the detectors and/or including additional detectors to ensure that the detector coverage provided is in accordance with the performance requirements.

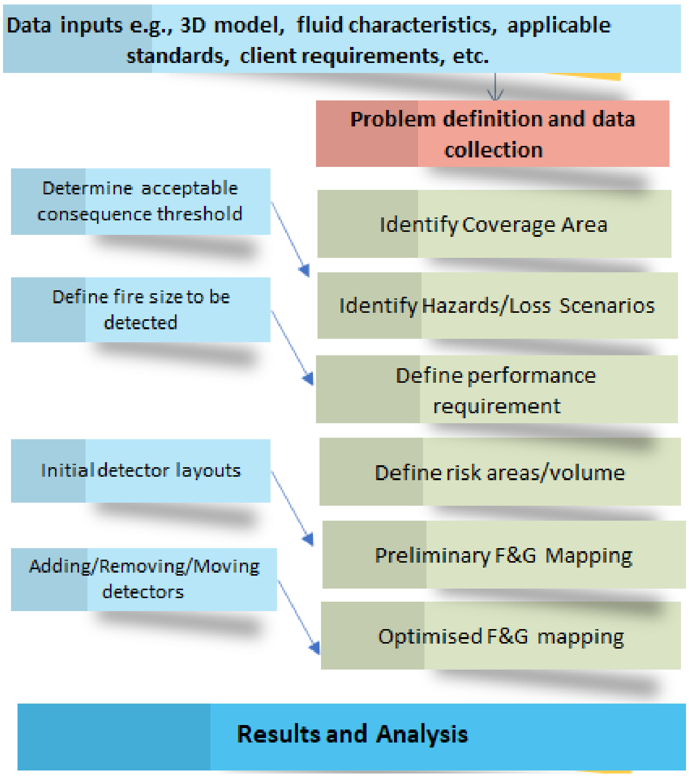

Figure 4: Methodology of the Assessment

Results

The results of the grading assessment indicate two hazard/graded areas have been assigned covering the equipment - High Hazard (HH) and Medium Hazard (MH) areas. The two different hazard areas are assigned different target fire sizes and coverage requirements. Figure 6**Error! Reference source not found.** shows the hazards area map for the deck level for all the cases. The HH area is assigned 90% coverage for both alarm and control action and the MH area is assigned 80% coverage.

The assessment has been carried out for the five different cases, ensuring the coverage target has been met for all the cases. Figure 5 shows the total flame detector count for the cases assessed, which range from five for case BS-1 to 11 for case ISA-3. The detector provision for the HH zone, which is the main driver for the required detector numbers is also shown.

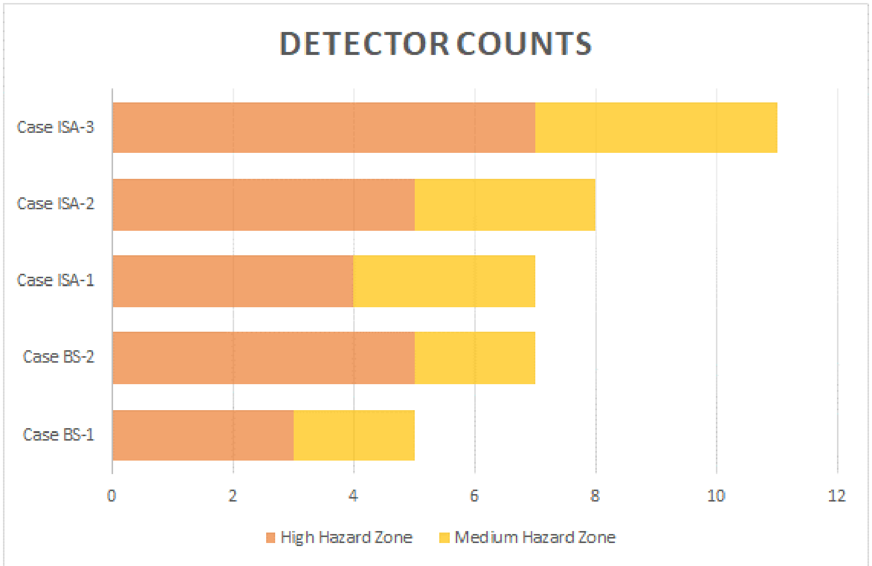

Figure 5: Flame Detector Numbers for Each Case for Performance Requirement Compliance

The F&G mapping coverage achieved is presented as both coverage statistics and a snapshot of the coverage image. **Error! Reference source not found.** Figure 6**Error! Reference source not found.** shows the results for the cases as 3D coverage and 2D coverage at 1.2m above the deck level. All the cases achieved the performance target of detecting a set fire for different zones and ensuring coverage is achieved for 90% of the HH zone and 80% for the MH zone.

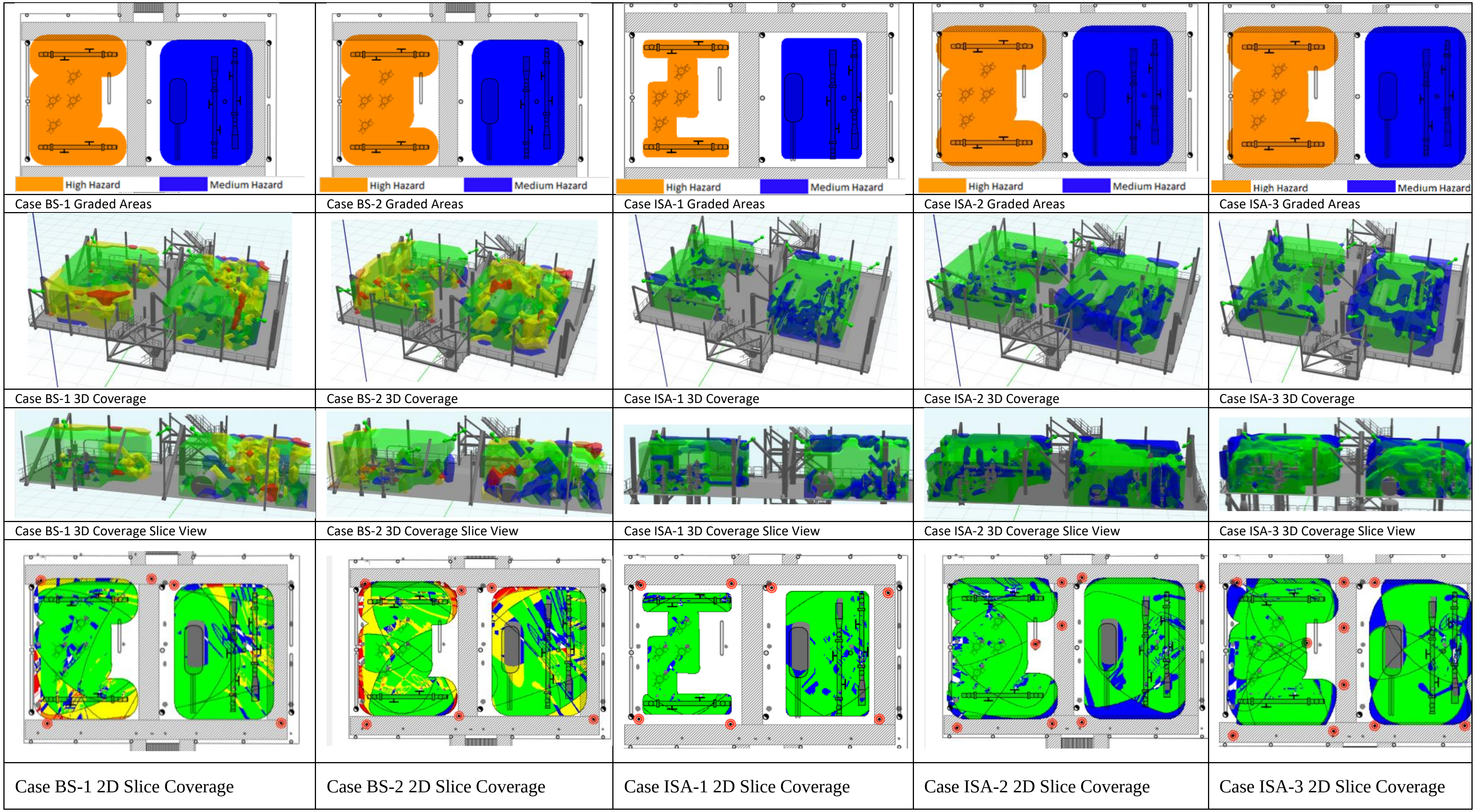

Figure 6: F&G Mapping Results Showing Graded Areas and Coverage Images

Discussion

The review of the different approaches to detector mapping has been carried out on a representative geometry and the results indicate subtle differences between ISA TR-84 and BS 60080 and also within each document, depending on the choices the user makes.

The mapping has been performed using the F&G mapping software DELOS. The results have been evaluated by conducting a comparison in terms of the number of flame detectors required to achieve the design coverage and meet the predefined performance target.

The results indicate that the coverage requirement and thus the number of detectors could vary by up to 100% depending on the approach adopted and the subjective choices made by the user. For instance, whilst cases BS-2 and ISA-1 require the same number of detectors to meet the performance requirement, ISA-3 needs about 60% more detectors compared to ISA-1 and more than double the number of detectors compared to BS-1. The differences in the features used for each case study are shown in Table 1.

From the assessment, it is observed that the major modelling decision with the highest impact on the detector count is the choice of using either the same or a different target fire size for alarm and control action. This can result in about a 50% change in detector count. For example, where a different target RHO is to be detected for control action compared to alarm, a reduction of up to 50% in the number of detectors is observed compared to where the same RHO target is used. All cases assume a minimum of 1ooN detection for alarm and 2ooN for control action.

The other choice with a significant impact is the decision on the detector's viewing distance. The user could either use the manufacturer's claimed detection distance or the "effective viewing distance" which reduces the detector test viewing distance by considering factors such as the detector's response in the presence of false alarm sources, reduction in sensitivity due to dirty optics, etc. This decision could result in the variation in the detector count by more than 30%.

Other variables such as the volume extension around the equipment being protected have minimal impact on the coverage requirement and detector count, as observed.

Figure 7 through to Figure 9 show the percentage changes in detector count for the whole deck and also for the different hazard zones for the cases modelled. It can be seen that the HH zone, with more onerous requirements and high consequences, has more detection requirements, and also results in higher differences in the required detector count between cases.

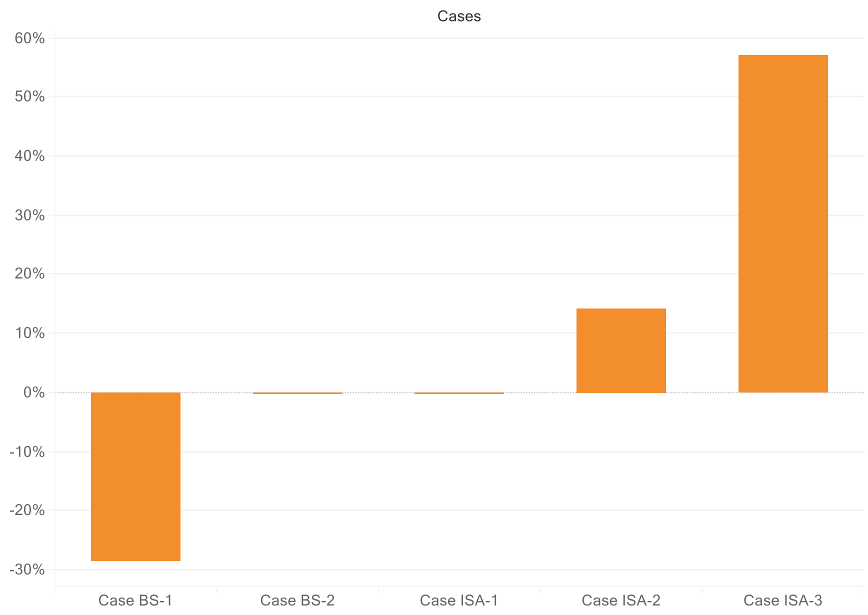

Figure 7: Percentage Change between Cases relative to ISA-1 – Total Detector Count

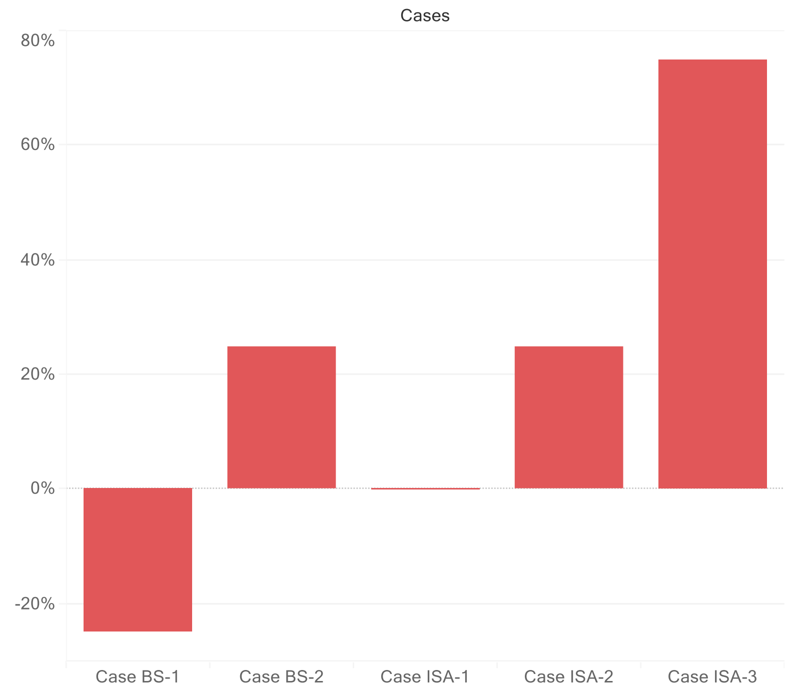

Figure 8: Percentage Change between Cases relative to ISA-1 – High Hazard Zone Detector Count

Figure 9: Percentage Change between Cases relative to ISA-1 – Medium Hazard Zone Detector Count

Conclusion

The results of the comparative analysis indicate that variation in terms of the F&G mapping outcome exists between the two standards but of more importance is the variation as a result of the judgement and choices the user makes. Within both standards, there are different design options that the user could choose, with each choice having a potential impact on the assessment outcome and the number of detectors required.

The review of the contents of guidance developed in the two standards indicates that they have been influenced by different methods in use by some major operators that have their in-house methodology. Perhaps to accommodate the various methods already adopted by some operators, the international standards have been written somewhat ambiguously and it, therefore, becomes difficult to have specific and direct guidance (McNay, 2017). Whilst this ambiguous approach is good for users with prior experience or those with other supporting guidance, other users could find that the outcome of their F&G

mapping assessment varying significantly depending on the judgement they make on what option within a standard to choose. For example, if the user decides to use the flame detector's effective viewing distance instead of the manufacturer's stated viewing distance, the assessment outcomes in terms of the required number of detectors could increase significantly.

In general, this assessment indicates that the BS 60080 approach tends to result in a fewer number of detectors for the same coverage compared to the ISA-TR-84 approach. This is because BS 60080 is more prescriptive and recommends certain features such as the use of different RHO for alarm and control action, from the typical example given. Conversely, ISA TR-84 lists different options and expects the user to make their choices, implying if a user makes choices similar to the BS 60080 recommendations, they will get comparable results.

This assessment indicates the importance of the experience and judgement of the F&G mapping engineer, and clear agreement of the performance requirement of the F&G system with the end user, including assessing different approaches and the likely consequence in terms of the number and placement of the F&G detectors. It is recommended that sensitivity analyses are carried out in order to better understand how the followed guidance is affecting the outcome. The suggested variables to change include prescribing different volume extensions around equipment, different ratios of RHO values for alarm and control action, different vendor flame detectors with different detection characteristics and extending the coverage representation to include late alarm and minimal coverage in addition to the traditional alarm and control action coverage.

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