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Research Article

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An Approach to Grid-based Fire Frequency Analysis for Design Accidental Loads in Offshore Installations

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Abstract

This paper describes the approach for establishing the Design Accidental Load (DAL) fire based on a grid-based fire risk analysis. Representative cases are screened via an initial fire risk analysis where the leak frequencies, ignition probabilities and inventories are combined to determine the cases with the highest risk. The fire risk analysis is subsequently performed based on the consequence results and the fire frequencies. Although many initiates for risk assessment were taken, there are many limitation and uncertainties on frequency analysis. Especially, calculation of ignition probability for an accidental hydrocarbon release on an offshore platform is a complex issue. To overcome these limitations of historical accident data, time dependent ignition model is developed a model for probability of ignition of hydrocarbon gas leakages on offshore platforms on based of ignition model presented by some JIPs for offshore risk assessment and improved understanding of ignition mechanisms. In this paper, we reviewed the existing probabilistic risk assessment method, such as ignition models, fire and explosion models, and selected the ones most suitable for offshore conditions. Then applied grid-based fire frequency analysis in the risk assessment. Two main revisions were incorporated: a grid-based approach was adopted to enable better consequence/impact modelling and analysis of radiation, and an enhanced onsite ignition model was integrated in the consequence assessment process to obtain better results. This study will be useful for the fire frequency analysis on offshore platform topsides as one of procedures of quantitative risk assessment.

Keywords: Risk assessment; Fire frequency; Design accidental loads; Offshore installation; Grid-based method

Introduction

The past few decades have seen a wide range of major accidents with a number of fatalities, economic losses and damage to the environment. Examples of accidents in the offshore oil and gas industry [1] include the structural failure and loss of platform, the flooding, a blowout, the process leak leading to fires and explosions on Piper Alpha in the UK, the explosion and sinking of production semisubmersible, and the recent helicopter accident on offshore platform. Experience shows that operational failures and human errors are the most common initiating events for accidents offshore. While operational failures could be arrested by safety-instrumented systems (through monitoring and restriction to the desirable limits of safety integrity level. Recently DiMattia et al. [2] have developed a unique human error probability calculation index for offshore mustering. The operational failures can be mainly attributed due to design faults or improper inspection and maintenance. An offshore development can never be completely safe, but the degree of inherent safety [3] can be increased by selecting the optimum design in terms of the installation configuration, layout and operation. This is done in an attempt to reduce the risk to a level that is as low as reasonably practicable (ALARP) without resorting to costly protective systems. This requires the identification and assessment of major risk contributors, which can be accomplished using quantitative risk assessment (QRA) techniques early in the project's life. If a structured approach of identification and assessment is not carried out early in the project, it is possible that the engineering judgement approach will fail to identify all of the major risks, and that loss prevention expenditures will be targeted in areas where there is little benefit. This may result in expensive remedial actions later in the life of the project [4].

Leakage or spillage of flammable material can lead to a fire that is triggered by any number of potential ignition sources (sparks, open flames, and so on). Depending on the types of release scenarios in the offshore environment, fires are mainly classified into four types: pool fires, jet fires, fireballs and flash fires. Although there are additional ones such as flares, fires on the sea surface and running liquid fires, they are in one way or the other modelled as one of the four defined types For example, flares can be treated as jet fires, and fires on the water surface and running liquid fires can be treated as pool fires. A review of the fire models and analysis of their characteristics has been carried out in our earlier work [5,6]. Jet fires usually occur due to immediate ignition of continuous high pressure releases. They represent a significant element of risk associated with major incidents on offshore installations, with the fuels ranging from light flammable gases to two-phase crude oil releases. Between horizontal and vertical jet fires, the former is more dangerous because of the high probability of impingement on objects downwind. This can lead to structural, storage vessel, and pipe-work failures, and can cause further escalation of the event. These are considered to be the most dangerous among all the fires, and hence need considerable attention.

The main aim of frequency and consequence analysis is to identify the personnel, equipment, plant and structure exposed to the initial and escalating events, and to assess the likely effects and failures. Frequency of fires is expressed in terms of leak probability and ignition probability. Also, the consequences of fires are usually expressed in terms of thermal radiation intensity, smoke concentration. The

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analysis of consequences resulting from a small process leak leading to major fires and explosions is shown in Figure 1. For an unwanted release event, the first step involved in analysing the consequences is to select an appropriate ignition, leak sources model based on the type and phase of release. The second step is to select a dispersion model to estimate the dimensions and concentration of the gas cloud. The third step is to select an ignition model to estimate the probability of ignition and the frequency of fire. The final step is to estimate the heat dose, and flame length from fires, and to evaluate their impacts (Figure 1).

In this paper, we reviewed the existing consequence models, such as source models, fire frequency models, ignition models for fire risk assessment, and selected the ones most suitable for offshore conditions. These models were then used to perform a consequence assessment for an offshore platform by simulating four different scenarios. Two main revisions were incorporated: a grid-based approach was adopted to enable better consequence/impact modelling and analysis of radiation, and an enhanced onsite ignition model was integrated in the consequence assessment process to obtain better results compare with current industrial practices.

The Proposed Approach

The present method is a combination of the conventional method and heuristic approach. The method consists of the following steps.

The probabilistic grid based assessment procedure for estimating jet fire loads is divided into two main sections as illustrated in Figure 2. First step describes the grid based approach for establishing the Design accidental Load (DAL) jet fire. Second step is determination of jet fire load. This step describes the approach for establishing the Design Accidental Load (DAL) jet fire based on a fire risk analysis. Representative cases are screened via an initial fire risk analysis where the leak frequencies, probability of immediate ignition and grids information are combined to determine the cases with the highest risk. These representative cases are further considered in the consequence assessment involving detailed fire load modelling with CFD and/or analytical solutions. The jet fire risk analysis is subsequently performed based on the consequence results and the fire frequencies. The output from the jet fire risk analysis is the jet fire exceedance plot which is used to assess the DAL jet fire scenario based on modelling of girds (Figure 2).

Grid-based modelling

A grid-based approach is one of the most straightforward ways to numerically compute a discrete probability distribution that approximate the continuous probability density function. This approach has found increasing popularity in mathematical, numerical and practical methodologies for complex systems due to their simplification of gird or segments divided from complex system. For example, the FPSO topside, an offshore installation is very compact with high degree of congestion and confinement due to space limitations and environmental conditions. In order to get the exceedance curve and the DAL jet fire of offshore installation, it should be determined by analysing all probable fires in the module, and obtaining the degree of consequence and the frequency for each jet fire. Generally, the dynamic fire loads can be calculated using CFD modelling and include all probable fire scenarios for target module or system [7-10]. However, the number of analyses required to do so will become too large. In practice, a selection of critical fires from the initial fire risk assessment can be applied.

Figure 1: Fire and explosion accidents in offshore installations.

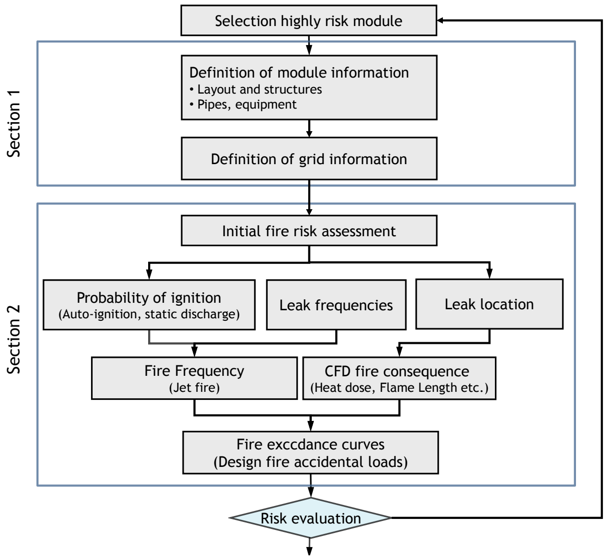


Figure 2: Proposed flow diagram of probabilistic fire accidental load procedure based on grid information.

In this study, the grid-based approach can be employed to enable better modelling of probability of ignition, leak frequencies, and analysis of fire consequence (flame length, heat dose etc.) at grids in the FPSO topside module. The grid modelling is need to details of number of pipes, equipments and layout of module information etc. of described the targe module in order to definition of grid information.

This approach is a grid of charge arithmetical values defined on an orthogonal lattice for calculation of fire frequency and fire consequence in Figure 3. The charge arithmetical values of grid can be obtained from numerical simulation, accidental data and probabilistic analysis based on grid modelling. The shape of grid in grid modelling appropriates orthogonal lattice then non-orthogonal lattices in order to easier modelling applied and combined to whole module information. If it is difficult to make an orthogonal lattice, the generalization to non-orthogonal lattices should be implemented considered with specific boundary conditions, significant complication, and detail of geometric properties (Figure 3).

Additionally, the analysis of radiation heat and the blast waves is uncertain if the presence of obstacles (partial barriers, e.g. process equipment and solid barriers, e.g. passive fire protection walls, explosion proof walls) is not taken into account. This issue does not arise when using CFD models, as application of appropriate boundary conditions will solve the problem. However, it appears to be difficult to resolve this issue while using semi-empirical models unless a grid-based approach is used [6]. The capability of this approach is apparent from Figure 4, which show the effect of partial barriers and solid barriers on the heat radiation from a jet fire. It is clear that the solid barrier totally blocks the radiation while the partial barrier reduces the effect to some extent. Also, the damage contours can be obtained permit the development of a clear picture of potential impact zones. This can facilitate proper selection and specification of safe separation distances to prevent injury to people and damage to nearby equipment. The grid heat load and overpressure load obtained from the analysis can also facilitate the design of protective layers. In addition, a grid-based approach seems to be most valuable for modelling of dispersing or expanding clouds (i.e., in dynamic simulation), and in defining risk (Figure 4).

A case is defined as a leak in a sub-segment where the sub-segment is the part of a segment which is located in one area. As a segment can be located in more than one area, it is often necessary to divide different segments into sub-segments. In this particular case, an area is defined as the area where a leak can have a direct influence. The area is limited by solid walls and decks and borders to free air. For larger areas e.g. a large area with smaller modules within the area, it is necessary to divide the area into sub areas. It is a good practice to make a schematic diagram showing the segments and the areas of the platform. This diagram can be made by combining the General Arrangement drawings and the Process and Instrument/Process Flow drawings of the main hydrocarbon carrying process equipment. When all segments and sub-segments are identified and located in the right area, a case list can be made. Often, a large segment has a small sub-segment in one area e.g. a riser segment which ends with an ESD valve in the import/export area [10]. This small sub-segment will have a large inventory and a small leak frequency, hence the risk can be significant and it is important to include it in the analysis.

Intial fire risk assessment

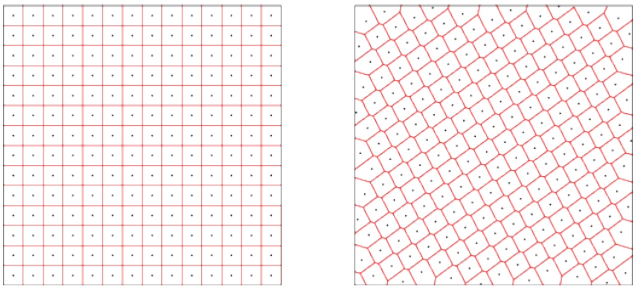
Fire frequencies

Leak frequencies: Leak frequencies and ignition probabilities are normally calculated as a part of a QRA and details are described in guidelines and standards such as references. It should be noted that leak frequencies need to be detailed for each sub-segment.

The inventory is defined as the mass of hydrocarbon (HC) in the segment (kg) and needs to be calculated for each segment. The volume applied is the volume inside the process equipment, bounded by the closed ESD valves. The density is calculated at the operating pressure. In a segment with different pressures, the settle-out pressure should be applied. Risk ranking of cases, when all cases are defined, the cases with the highest combination of fire frequency and inventory have the highest potential risk. These are the cases which are applied as representative for the detailed consequence analysis. The parts of the fire case regarding location and leak rates and wind conditions are considered in the next section. It is noted that the simplifications arising from modelling only a few cases with simulation tools and using those cases as a basis for representing all fires is justified partly because the analysis method applied leak rates and not whole sizes to represent the cases. Using this approach, a case with a low pressure and a large hole will be defined in a similar way to a case with high pressure and smaller leak hole.

Probabilities of ignition: Source models or release models [11-13] are used to estimate the amount of fuel released, or the rate of release of fuel. These models play a crucial role in the risk assessment process as the release rate and quantity of fuel released determine the size of the resulting cloud and hence the probability of ignition. Furthermore, these models are also used to find the initial sizes of fires and explosions. The initial release rate through a leak depends mainly on the pressure inside the equipment, the size of the hole and the phase of release. Offshore hydrocarbon releases are usually gaseous, liquid and two-phase. Among these, the gases can be hydrocarbons ranging from C1 to C4, while liquids can be crude oil, diesel oil, aviation fuel, and others. Condensate is considered to be two-phase as it is a mixture of hydrocarbons (mainly C4 to C6) that condenses from the gas during compression. This material is liquid while it is held under pressure but becomes gas if the pressure is released. Identification of the appropriate phase and its corresponding model is essential, as, this being the initial step for risk assessment; it may prove to be highly sensitive to the risk estimated.

The probability of immediate ignition depends upon both the potential for auto-ignition (Pai) and the potential for static discharge (Psd). In this model, the former is related to the release temperature (T) relative to the auto-ignition temperature (AIT), and the latter to the minimum ignition energy (MIE) and "release energy" for the material being released. The "release energy" may be considered a function of the process pressure, or release rate, or yet some other surrogate parameter that expresses the often observed result that the more "energy" behind a release, the more likely it is to ignite. Expert Opinion e Subject matter experts were solicited to predict the expected probability of immediate ignition for a variety of hypothetical release scenarios, based on their experience with similar events in process plants. This resulted in an algorithm which was based on MIE, T and AIT. The available static "energy" was the fourth parameter, and was independently developed as a function of the square root of the process pressure. Another work in this area [14] by three recognized experts proposes that the immediate ignition probability is roughly



(a) Orthogonal Lattices (b) Non-orthogonal lattices

Figure 3: The typical gird modelling as a two-dimensional matrix form.

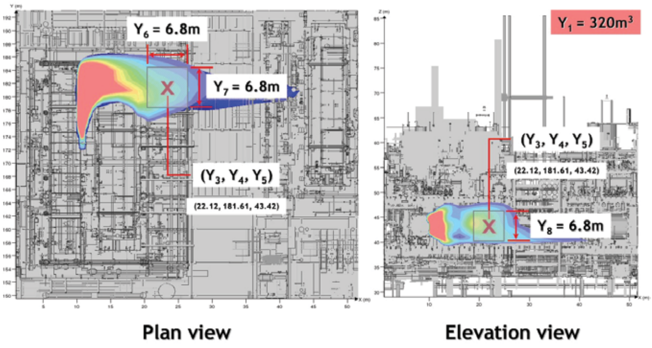


Figure 4: Jet fire heat radiation in the presence of solid and partial barriers.

proportional to the cube root of the flow rate of the release. In contrast, the square-root-of-pressure relationship proposed independently is equivalent to indicating that this probability is linearly proportional to the release rate. Given this conflict, a compromise is proposed in which the probability of immediate ignition is proportional to the cube root of the source pressure.

The approaches above were combined, resulting in the following relationship [13]:

$$P_{imm.ign} = Pai + Psd \tag{1}$$

$$P_{imm.ign} = (1 - 5000e^{-9.5(T/AIT)}) + (0.0024 \times \frac{P^{1/3}}{MIE^{2/3}}) \tag{2}$$

Where AIT and T are in degrees AIT and T are in degrees Fahrenheit, P is in psig, and MIE is in mJ. The following constraints are place on this equation: a minimum value of 0 is allowed for T, For $T/AIT < 0.9$, $Pai = 0$, For $T/AIT > 1.2$, $Pai = 1$, and $P_{imm.ign}$ cannot be greater than 1.

In this method, it is assumed that there is always some probability of non-immediate ignition if T is no more than 200° higher than the AIT (this 200° factor being necessary because AIT values in the literature vary widely for many chemicals, depending on the investigator/apparatus used to measure it). If this condition is met, then $P_{imm.ign}$ is prevented from having a value greater than 0.98. Table 1 lists representative MIE and AIT values for four common chemicals. Values for many other chemicals are provided in Bond [15-17].

Figure 5 shows ignition source parameters for determining the probability of ignition at each grids by Equations 1 and 2. The ignition probability will be calculated using potential probability of the counted equipment (Figure 5).

Leak rate: Leak frequency per offshore platform can be identified on the basis of historical data and presented as a function of the leak amount, where this amount is the product of leak rate and leak duration. Currently, actual data are available for a ten-year period, 1996–2005, for all installations on the Norwegian Continental Shelf. The quality of the data is good for the 2001–2005 periods, and this should be the main data source. Figure 2 shows the trend of hydrocarbon leaks with a flow rate above 0.1 kg/s, normalized against installation years, for fixed production installations. These data are taken from the PSA annual report for 2008 (Figure 2) [18].

In addition, the Health and Safety Executive (HSE) has compiled a database of floating production, storage and offloading unit (FPSO) leak frequencies in association with leak amounts (amounts of fuel released) and the number of FPSOs. This report briefly examines release trends over the data range of interest and provides the total number of releases that occurred each year between 1980 and 2003 [19].

The definitions of the three groups are categorised based on the amount of fuel released are as follows into major, significant, and minor categories. Major releases have a rapid and significant impact on the local area, and typically affect temporary refuges, block escape routes, escalate to other areas of the installation, and cause serious injuries or fatalities. Significant releases cause serious injuries or fatalities among personnel within the local area and escalate within that local area, such as by causing structural damage, secondary leaks or damage to safety systems. Minor releases cause serious injury to personnel in the immediate vicinity, but are very unlikely to escalate or cause multiple fatalities.

Fire location: The number of fire locations depends on the size of the process area. For an average sized process area, two or three locations should be appropriate. Typically, one location near the centre, and others near the edges should be selected. In addition, the leak location needs to be placed where there are pipes and equipment belonging to the representative cases.

Leak positions comprise one of the most important parameters of gas detector placement. On production platforms with complex process trains, leaks from process equipment are inevitably relatively frequent events. In most cases, they are small and readily controlled. Occasionally, they develop into explosions and fires. Very infrequently, they may escalate into major accidents such as the one that occurred on the Piper Alpha oil platform. Leak positions are difficult to consider [20].

For convenience, it can be assumed that the range of leak positions in x-, y and z-directions is based on the confinement of the piping and vessels causing a leak inside the production platform. Also, leak directions can be considered with regard to the leak points.

Jet direction: The jet direction should be selected so that both long jets and impinging jets are simulated. The long jet needs to be directed in the horizontal direction where it is not hitting large equipment and where it is still within the process area. Impinging jet directions are down/up into solid decks, or horizontally hitting a firewall or a large piece of equipment. The impinging, diffusive gas fire could be represented by a low velocity release, although the most realistic diffusive fire is obtained with a high speed release impinging on a solid structure. The number of jet directions can be reduced by not simulating jets where the jet fire will be directed out of the area. Typically 2 or 3 jet directions need to be simulated, one diffusive impinging jet, and two non-impinging jets which cause the majority of the flames to be located inside the area.

Wind conditions: Wind speed and wind direction have less influence on the flame location and the extreme heat loads than the previously mentioned parameters. The strong momentum and buoyancy in the

Material	MIE (mJ)	AIT (F)
Hydrogen	0.011 [15]	752-1085 [15] 752 [16]
Methane	0.28/0.3[15]	999-1103 [15] 999 [17] 1004 [16]
Propane	0.12/0.48[15]	842-912 [15] 842 [16, 17]

Table 1: Minimum ignition energies and auto-ignition temperatures for some common chemicals.

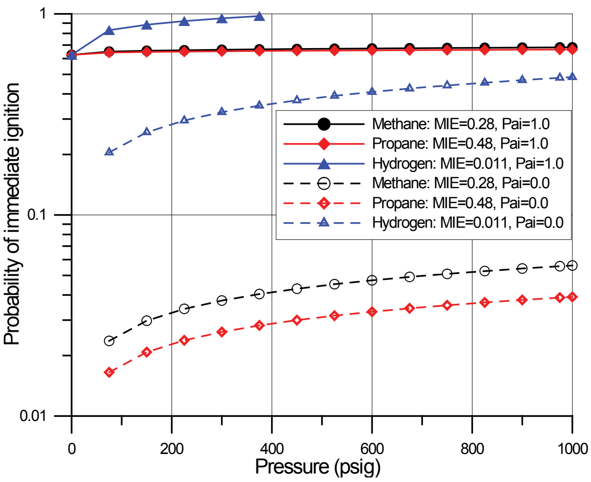


Figure 5: Probability of ignition model of varying gases.

upstream parts of a fire are dominating over the wind momentum; hence wind conditions have a lesser influence. For diffusive, large fires the flames will generally follow the wind direction through the process area; hence, the wind direction should be selected so that it blows the flames mostly into the process area. The wind direction should be selected together with the fire location and jet direction so that most of the fire burns inside the process area. Symmetry conditions can be utilised where appropriate and simulations can be performed on one side, applying the same results on the symmetric opposite side without simulating it. In cases where the wind speed and direction have a significant influence on the fire loads, the wind rose can be applied to assess the impact probability. Note that smoke movement is mostly driven by the wind and in cases where the fire simulations are used for smoke dispersion patterns, the wind conditions need also be considered.

Fire consequence modelling: Fire load modelling using a simulation tools can be performed after the initial fire risk analysis described above and is an input to the probabilistic analysis. Heat loads to be used in the analysis are obtained based on CFD and/or analytical models that are validated against research and experiments. The probabilistic procedure involves a finer distribution of heat flux as a function of leak rate and time compared to traditional methods. The procedure hence accounts for higher heat loads for larger fires as well as dynamic effects. The upper cut-off should reflect the maximum credible initial leak rates. Normally, this would reflect a pipe rupture scenario. Note that the full bore scenarios are in most cases of a very transient nature, and the initial leak rate should represent a typical, average leak rate which occurs in the period before ESD valves are closed. When the QRA gives leak frequencies in only 3 categories, the sub-division of the leak frequency in the smaller categories should be documented [7-9].

Fire exceedance curves: Establishing the fire exceedance plot involves the combination of consequences, probabilities and frequencies to determine the fire risk. The fire exceedance plot is the main result from the probabilistic fire analysis. The generation of the plot for a complex process area and dynamic fires is described. Results from the above sections are used. The fire load to be used on the x-axis of the plot is defined as the heat dose, Temperature received at a spot value. The fire exceedance plot is also used to pick there preventative dynamic fire scenario which is used in the structural response analysis. The requirement for the x-axis is that all fires with a lower x-value than the DAL fire value must be considered in the design. Fires with a higher x-value than the DAL fire need not be designed against because these have too low frequency. When the x-axis is defined correctly, it will be enough to design the mitigating measures using the DAL fire only, and it is not necessary to design against any fires with smaller severity.

Determination of design of fire load: This dynamic behaviour of the fire load is more important for pipes and equipment than for structures. This is because the pipe stress is strongly dependent on the pressure in the pipes and hence pipes are more vulnerable to high heat loads at the start of the fires before the pressure is relieved by blow-down. For pipes and equipment, one can use a set of DAL fires which has the same heat dose when performing the heat-up and response calculations. The set can be selected from the CFD simulations as realistic heat flux vs. time curves. Separate exceedance curves for different durations of the heat flux can also be made so that the separate frequency for the different durations can be found. The extent of the fire and the average heat flux in the area is also important for pipes and equipment as this determines the general heating the piping and equipment receives.

The main output form the first part of this probabilistic procedure is the exceedance curve and the DAL fire. This is determined by analysing all probable fires in the module, and obtaining the degree of severity (consequence) and the frequency for each fire. Ideally, the dynamic fire loads are calculated using CFD modelling and/or analytical solutions and include all probable fire scenarios. However, the number of analyses required to do so will become too large. In practice, a selection of critical fires from the initial fire risk assessment can be applied. Such critical fires are called cases in this procedure.

Application Examples

A simple generic case study is provided to illustrate the benefits of the developed approach. The topside of a hypothetical FPSO is considered as an applied example, and a three-dimensional view of the topside is depicted in Figure 6 [8]. The topside module is divided into a process area and a utility area. The former includes space for hydrocarbon-containing equipment, the flare tower, and compression and separation equipment, whereas the latter includes space for utility and power-generation equipment. In this application example, the one of process module on FPSO topside are selected for calculation of fire frequency analysis and consequence analysis. The process decks on FPSO topside are usually either grated decks or plated decks. The former are more convenient for draining rainwater, and they ventilate gas clouds in fires by minimizing the fire-induced temperature, whereas the latter are more useful in preventing the escalation of fire from the lower to the upper deck (Figure 6). In separation module under consideration here, the lowest process deck in plated and the middle and top decks are grated (Figure 7).

For grid-based computation, the process area under study is divided into a specific number of computational or/and manual grids, and the hazard potentials and consequences are then evaluated at each

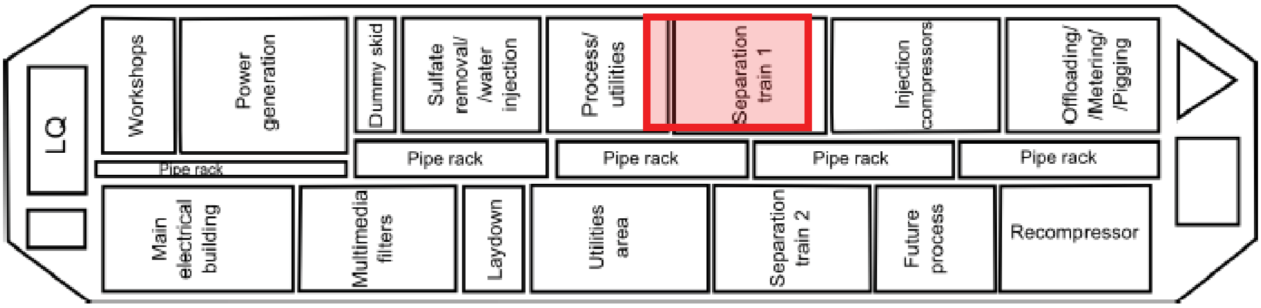


Figure 6: Layout of the object FPSO topsides.

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end of the grid. This leads to a two-dimensional or three-dimensional matrix of hazard and consequence results which can be finally plotted as contours. Contour plotting is a more user-friendly representation than the ordinary line plots obtained by other software packages. It can be performed extensive trial simulation runs on process area to study the effect of number of grids.

To obtain the leak frequency should be identified and determined by a two-dimensional or three-dimensional space. In this study, length, breadth, and height are divided by uniformly spaces (Figure 8). Sensitivity of course grids space should be bigger affected then fine grids. Therefore, the computational time and the precision of results for plotting were found to be the most important as well as highly sensitive parameters on the application of a grid system.

Table 2 shows the definition of leak source parameters for determining the frequency of leak at each grid. In the case study, leak frequency for selected equipment is obtained by HSE database [19]. Then it can be counted number of equipment in each grid. Table 3 shows the definition of the location grid matrix used to identify the location of each grid for leak frequency analysis. The results of leak frequency show that Area C is the highest value due to numbers of pipes and values equipment located in Area C. The initial potential gird areas can be revised by increasing the grid numbers, it will be more accurate results for leak frequency.

Equipment type	Index Name	Location	Frequency	Numbers
Separator (HP, LP, IP, Desalter)	SEP.	A,B,C	0.0026	4
Pump (Produced water booster, Desalter water, Crude oil transfer)	PUM	A,B,C	0.0073	9
Crude oil transfer cooler	COL	B,C	0.0053	1
Crude oil heater and exchanger	EXC.	C	0.0060	3
Hydro-cyclone package and Produced water gas flotation unit	UNI	A,B,C	0.0007	4
Piping	PIP	A,B,C	0.000068	5500
Flange	FLA	A,B,C	0.000055	5500
Valves	VAL	A,B	0.0001	5000

Table 2: Leak frequencies per equipment item and numbers of equipment.

Grid	Leak parameters and number								Leak Frequency	
	SEP	PUM	COL	EXC	UNI	PIP	FLA	VAL		
A × U	1	0	0	0	1	400	400	200	0.0718	0.1915
A × M	0	0	0	0	0	300	300	150	0.0519	
A × L	0.5	2	0	0	0	300	300	150	0.0678	
B × U	0	0	0	0	2	800	800	400	0.1398	0.2437
B × M	0	0	0	0	0	600	600	300	0.1038	
B × L	0.95	4	1	0	0	600	600	300	0.000065	
C × U	1	0	0	3	1	1,100	1,100	500	0.2066	0.4721
C × M	0	0	0	0	0	700	700	350	0.1211	
C × L	0.55	3	0	0	0	700	700	350	0.1444	

*notes: H.E. is Heavy equipment, M.E. is Medium equipment and L.E. is Light equipment.

Table 3: The calculation of leak frequencies for Area A, B, and C.

Table 4 shows Ignition source parameters for determining the probability of ignition at each grids by equations 1 and 2. Probability of ignition was estimated using the developed ignition model when the cloud concentration is within the flammability limits. The ignition probability can be calculated using potential probability of the counted equipment. As would expected, Area C is also highly ranked compared with others.

Grid number	Potential probability					Probability of ignition	Rank
	Auto-ignition			Static discharge			
	T(F)	AIT(F)	T/AIT	P(psig)	MIE(mJ)		
A × U	150.98	919	0.164	50.70	0.25	0.02238	9
A × M	150.98	919	0.164	50.70	0.25	0.02238	8
A × L	123.30	999	0.123	66.25	0.28	0.02269	7
B × U	123.30	999	0.123	50.70	0.28	0.02075	6
B × M	123.30	999	0.123	50.70	0.28	0.02075	5
B × L	123.30	999	0.123	127.9	0.28	0.02825	4
C × U	150.98	1,085	0.139	50.70	0.011	0.17959	3
C × M	150.98	1,085	0.139	50.70	0.011	0.17959	2
C × L	150.98	1,085	0.139	118.48	0.011	0.23832	1

*notes: H.E. is Heavy equipment, M.E. is Medium equipment and L.E. is Light equipment.

Table 4: Ignition source parameters for determining the probability of ignition at each grids.

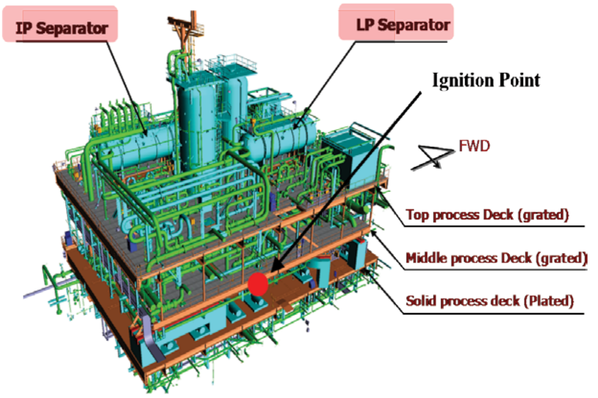

Figure 7: Isometric view of a typical separation module.

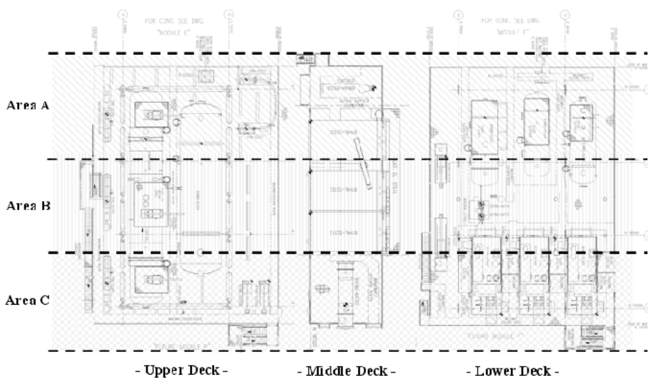

Figure 8: Plan view of separation module.

To obtain the characteristics of the gas clouds in each fire frequency and consequence of jet fire, in this study uses and verifies the DNV PHAST [20] results when simplified release modelling is sufficient. DNV PHAST was used to provide time-dependent descriptions of the gas clouds for the gas leak scenarios considered in the study. The study considered only cloud dispersion in two dimensions. The data provided by DNV PHAST included the time-based history of the gas cloud length, width and size at 20%, 50% and 100% LFL.

Scenario 1: jet fire due to ignition of a gas cloud formed by an instantaneous release (IR) of 100 kg of methane gas over the process area; a continuous release (CR) of gas at 1.0, 1.5, and 3 kgs due to leak in a storage tank. The gas that is released (instantaneously or continuously) forms a cloud and disperses with initial momentum in low wind conditions. The dispersion of these clouds and jet fire were simulated using a DNV PHAST dispersion model and jet fire model to estimate the dimension of the cloud and jet fire. These results are presented in Figure 9 and Table 5 for all scenarios (Figure 9).

Flame length contours obtained as a result from the scenario show that most of the Area C is affected, whereas the contours from the Area A and B scenario show that relatively a very small part of the plant is affected. With this we can conclude that jet fire from current simple scenarios is the more dangerous event.

The example of the initial fire risk analysis is to get an overview of the fire cases and the potential risks involved. This is used to obtain a preliminary risk ranking of the cases which are used to select representative cases for further detailed consequence analysis.

Conclusion and Remarks

This paper describes the approach for establishing the Design Accidental Load (DAL) fire based on a grid-based fire risk analysis. Representative cases are screened via an initial fire risk analysis where the leak frequencies, ignition probabilities and inventories are combined to determine the cases with the highest risk. In this paper, we reviewed the existing probabilistic risk assessment method, such as ignition models, fire and explosion models, and selected the ones most suitable for offshore conditions. Then applied grid-based fire frequency analysis in the risk assessment. Two main revisions were incorporated: a grid-based approach was adopted to enable better consequence/impact modelling and analysis of radiation, and an enhanced onsite ignition model was integrated in the consequence assessment process to obtain better results. This study will be useful for the fire frequency analysis on offshore platform topsides as one of procedures of quantitative risk assessment.

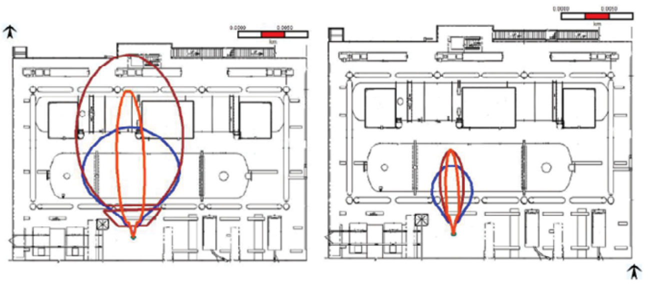

Figure 9: Plan view of gas clouds (left: Area C, right: Area A).

Grid number	Probability of ignition (/year)	Leak Frequency (/year)	Fire Frequency (/year), F	Flame Length (m), C	Risk =F × C	Rank
A × U	0.02238	0.0718	0.001607	7.2	0.0115704	6
A × M	0.02238	0.0519	0.001162	7.2	0.0083664	8
A × L	0.02269	0.0678	0.001538	7.2	0.0110736	7
B × U	0.02075	0.1398	0.002901	13.5	0.0391635	4
B × M	0.02075	0.1038	0.002154	13.5	0.029079	5
B × L	0.02825	0.0000646	1.82E-06	13.5	0.00002457	9
C × U	0.17959	0.2066	0.037103	19.8	0.7346394	1
C × M	0.17959	0.1211	0.021748	19.8	0.4306104	3
C × L	0.23832	0.14443	0.034421	19.8	0.6815358	2

*notes: H.E. is Heavy equipment, M.E. Medium equipment and L.E. is Light equipment.

Table 5: Fire frequency and fire consequence results.

Acknowledgment

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