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Monitor Points Selection in CFD FLACS for Gas Detector Placement

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Abstract*: Gas detector first invented was in 1815 to detect the presence of the methane gas and becomes part of a safety system when it is capable to detect the gas leakage and decrease the risk of major accident occurrence. However, the efficiency of the gas detector has been questioned among industry people due to unable to measure the effectiveness of the gas detector quantitatively. Industry people has a problem on how many and where should they locate the gas detector. This study explained the very beginning steps on how to determine the number and location of the gas detector should be installed. This research simulated the gas explosion cloud by using CFD FLACS at highly hazardous area by setting the four parameters with different values of wind speed, wind direction, leak rate and leak direction. In order to optimize the placement of the gas detector, three objectives need to be achieved: 1) to obtain the fastest response time of the gas detector to any gas leakage, 2) to ensure the availability of the gas detection system in worst conditions and 3) to place the gas detector in the potentially hazardous area. The locations of the gas detector meet the objectives based on the approach applied in this study.

Keywords: CFD FLACS, FGS placement, gas detection system, gas dispersion, modelling.

I. INTRODUCTION

Oil and gas plant is one of the perilous plants especially for employees on oilrigs where large inventory of highly combustible materials, the threat of swinging cranes and the hazard of dangerous, heavy equipment causing 6000 offshore accidents and incidents from 1970 were reported [1]. For the Deepwater Horizon incident, the accident investigation report stated that one of the key findings is the fire and gas detection system did not prevent hydrocarbon ignition. Automated function in the alarm was not included in the gas detection system for the engine room HVAC fans and dampers probably because they do not want the false gas-detection trips to interrupt the power supply [2].

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In the Buncefield incident investigation final report also has stated that the emergency responders should be improved in terms of the arrangement to be readily available before the incident happen [3]. These incidents indicate how significant the fire and gas detection system to safety in order to mitigate a huge damage loss. The incidents were highly tragic proved by "Accident Statistics for Floating Offshore Units on the UK Continental Shelf 1980-2005" where the highest increasing number in incidents is 1673 incidents for mobile drilling units [4]. The CMPT Standard also reported that only 4 out of 133 fires in the Norwegian North Sea were detected by gas detectors [5]. The NORSOK Standard [6], ISA-RP12.14-Part II-1990 and API Publication 2031 [7] do not have a clear guidance on the spacing and number of the gas detector. It depends on the expertise of the experienced engineer to place the gas detector [7]. Thus, different industries will have different techniques to place the gas detector. Unfortunately, the incident still happened even the hazardous area was equipped with the gas detector. The CMPT DNV Standard, OGP Standard and PTS (PETRONAS Technical Standard) are the guidelines referred by most industries in Asia recommend a gas dispersion approach for gas detector layout. However, there are some industries considered the wind speed as the input data for the gas dispersion and do a calculation to determine the size of the cloud for different wind directions. Computational Fluid Dynamics (CFD) FLACS known as FLame ACceleration Simulation assist in defining the realistic cloud sizes as the consequence of a flammable gas release on an offshore platform [8]. This study simulated the gas dispersion in CFD FLACS where this software is widely used in industry. CFD FLACS also is highly recommended since it is useful when the industrial areas are occupied with many pipe racks, tanks and other types of obstacles [9] and fully supported by A.J. Benavides-Serrano when he stated that CFD is able to simulate dispersion scenarios having complex geometries [10].

This study focusses more to four parameters which are wind speed, wind direction, leak rate and leak direction. The offshore installation area usually is being exposed to severe wind conditions. The velocity of the air caused by the wind and the leak rate in the leakage point able to change the direction of escaped gas from a leak. Once the gas is released and mixed with air, the density of the gas is very similar to that of air, so the buoyancy effect is easily overcome by local air flows. The gas accumulates in the same place and this is considered as the worst-case scenario due to the gas detector is not installed in the right place. This indicates that wind speed plays a significant role in the positioning of the gas detector as it can affect the size of the gas cloud.

The wind direction in the simulation of the gas release should be considered. The NORSOK Z-013 standard recommends that at least 8 wind directions are considered for the ventilation simulations [11]. However, due to time constraint, this study focuses only two directions which are x+ and x-.

Dependent on ventilation conditions and whether the gas leak is placed in a confined area a certain leak rate must exist in order to form a potentially dangerous cloud [12]. Increasing the leak rate will result in a high gas concentration area. Leak direction could influence the dispersion path of the released gas. The leak directions might seem to have no significant impact to flammable gas cloud size since the wind direction is the most crucial impact. Nonetheless, when there is no wind speed, the leak direction may have a significant impact where the gas accumulates at one place according to the leak direction.

The plant layout was taken from an offshore platform located in Asia. The plant consists of turbine exhaust, Low Pressure (LP) Production Cooler, chlorine storage tank, demulsifier storage and reverses demulsifier tank. In order to identify the placement of the gas detector, three objectives are included: 1) to obtain the fastest response time of the gas detector to any gas leakage, 2) to ensure the availability of the gas detection system in worst conditions and 3) to place the gas detector in the potentially hazardous area.

II. METHODOLOGY

The following steps are for placement of the gas detector.

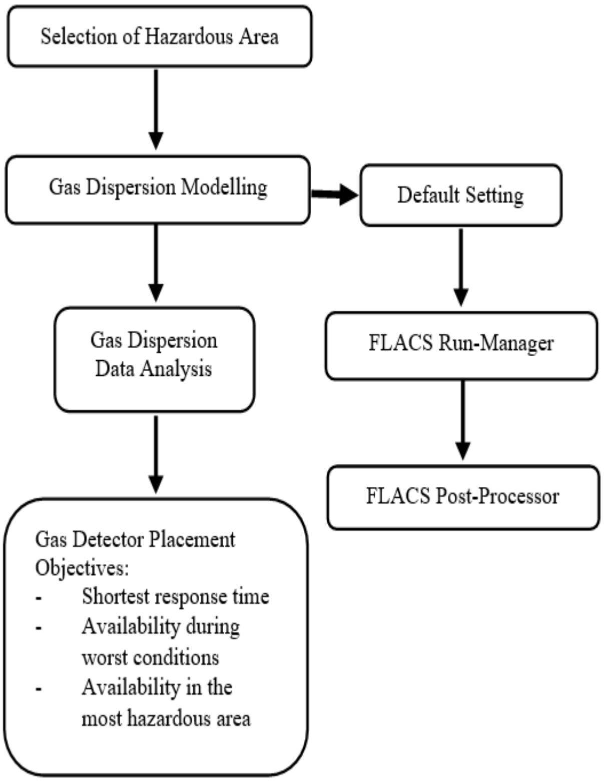

Fig. 1 The steps for gas dispersion simulation and gas detector placement

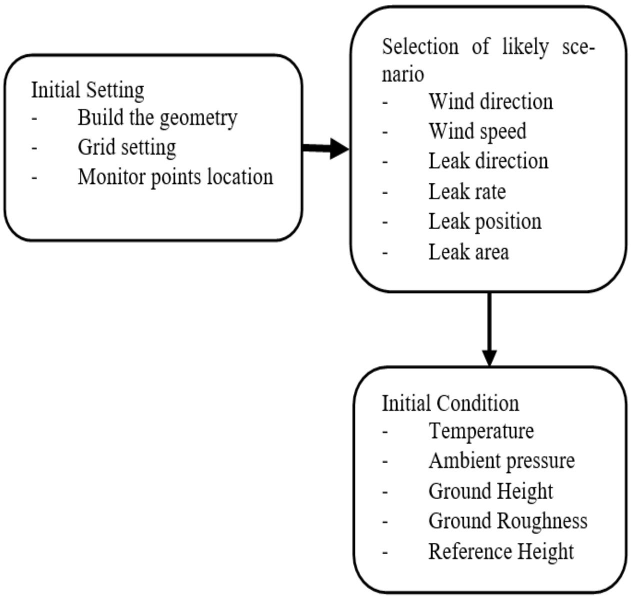

Fig. 2 The steps in a default setting

A. Default Setting

For this study, the geometry was taken from the offshore platform located in Asia. The selection of the zone hazardous area is based on the existing of the gas detector in the current layout. The gas detectors installed in that area are two types which are the point gas detector and open-path gas detector using infrared (IR) technology. Apparently, the layout chosen is one of the zone hazardous area because it consists of turbine exhaust, LP production cooler, chlorine storage tank, demulsifier storage and reverses demulsifier tank. The potential gas leakage is from LP production cooler where it contains flammable gas with high temperature and pressure. The chosen geometry was drawn in CFD FLACS by using boxes and cylinders as per Fig. 3. Mesh sensitivity can affect the simulations and results based on geometry. In order to choose optimum number of mesh to be used for the current geometry, grid size was changed progressively. Based on mesh sensitivity, 1m grid size was used for the dispersion modelling. Monitor points 227 were set in the simulation. Monitor points can measure the concentration as the gas releases. Hence, in this study, these monitor points can be assumed as gas detectors to install in the geometry. For the leak scenarios, the leak area was given 0.04 m^2 with 0.23 m leak diameter. The input data of the four parameters were set with different values. Initial conditions were set for turbulence fields, temperature and pressure at the beginning of the simulation. Information about the gravity conditions, parameters for the atmospheric boundary layer and the composition of the air was also set.

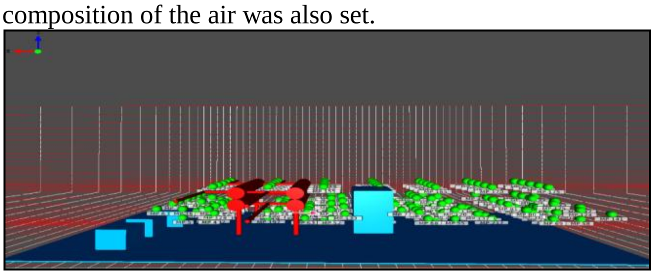

Fig. 3 Geometry with grids and 227 random monitor points

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B. FLACS Run Manager

After all the cases have been created in each folder, FLACS run manager window was opened. In FLACS run, cases folders can be added in "Add Directory" button, once they are added, they were porcalc and simulate. To simulate several cases, "Batch Run" button can be used. While it was simulating, time vs. rate, pressure, fuel, velocity or other variables can be seen. If there is error occurred, the error can be found in Log File. After all the simulations are done, Green colour with FINISHED statement can be seen.

C. FLACS Post-Processor

Flowvis is the post-processor for the FLACS and it is also a program for visualizing results. The icon can also be found in the FLACS run manager window. Gas dispersion (3D cut plane) and time vs. concentration (scalar time) results can be obtained from flowvis as well. In this study, scalar time was required for data analysis. Each monitor points will have a different trend of scalar time due to wind speed and leak rate.

D. Gas Detector Placement

Monitor points play an important role as it recorded the concentration of the gas for a certain area. Three objectives in determining the strategic placement of the gas detector need to be achieved:

- To obtain the fastest response time of the gas detector to any gas leakage.
- To ensure the availability of the gas detection system in the worst conditions.
- To place the gas detector in the most hazardous area.

III. RESULTS & DISCUSSIONS

As mentioned in the methodology section, the results of the FLACS can be taken from flowvis. Results from the FLACS simulations (36 cases) were the concentration of each monitor points for all cases. Geometries in XY plane was taken in order to see the difference between each of the scenarios. In this research, leak position is at x=22 m, y=5m, and z=1.5m. By analyzing the concentration for each monitor points (MP), there are 21 MPs that can detect the 5% to 15% concentration. The MP act as gas detector since it can detect the percentage of methane concentration and 21 MPs are pretty much for gas detector placement for area 14.5m width and 26.1m length. Thus, there will be three ways for MP's selection which are:

A. The nearest MP location to leak location

The objective of the gas detector placement is to obtain the shortest time taken for the gas release to be detected. In order to reduce the number of selections for this case, the monitor point in a range distance between 17m and 27m for X-axis from the leak location (22, 5, 1.5) m will be analyzed to choose the shortest time taken to detect the flammable gas. The shortest time taken shall be not exceed the time taken for the explosion to happen. The explosion triangle (i.e.: fuel, ignition source and oxygen) is the causes that lead to fire and explosion. By considering the ignition source for certain area, the time taken for the explosion shall be calculated. Fire and Explosion Analysis (FERA) is one of the safety studies analyse the explosion with several factors. It is recommended to take the FERA study as a basis for this case.

B. The worst-case conditions

It is not easy to choose the optimum condition when it comes to safety thing. The worst condition in which the dispersed gas reaches the detector later in comparison to the other cases. Logically, the worst condition is qualitative assessment where it can be changing from time to time based on the several factors (e.g.: wind speed, wind direction, geometry, etc). Based on the scope of the worst condition as mentioned before, the lowest wind speed is one of the causes to the worst condition. For example, when the wind speed is 0m/s, the gas cloud will not spread out and causes the gas detector unable to detect the gas and gives warning to personnel on the facilities. Secondly, the leak rate will be the highest amount of loss containment as it is major threat lead to fire and explosion. In this study, the lowest wind speed is 3m/s and case 25 (Table 2), case 26 (Table 3), case 31 (Table 4) and case 32 (Table 5) are being chosen because the leak rate is the highest which is 10kg/s as can be seen in **Error! Reference source not found.**.

Table 1 the worst-case conditions

Cases	Height (m)	Leak Rate (kg/s)	Leak Direction	Wind Speed (m/s)	Wind Directi on
25	1.5	10	+x	3	+x
26	1.5	10	+x	3	-x
31	1.5	10	-x	3	+x
32	1.5	10	-x	3	-x

The gas detector well performed when it is operated during the demand scenarios. By considering the worst-case, the placement of the gas detector is optimized where it covered the highly flammable area. The gas detector should be in place where it can detect the flammable gas in a worst-case within the short time taken. Thus, the chosen monitor points in the worst-case will be the shortest time taken to detect the 5% concentration.

- Case 25 Plot Simulation

Table 2 shows the results at time 4.97 s until 5.3 s. The label indicates the first monitor point that capable detects 5% concentration of methane gas. Monitor point 30 (MP 30) detects 5% concentration at time 5.01 s.

Table 2 Time taken for flammable gas detection

Time (s)	MP 30	MP 64	MP 54	MP 53	MP 41
4.97	0.0000	0.0000	0.0000	0.0000	0.0000
5.01	0.0004	0.0000	0.0000	0.0000	0.0000
5.06	0.0037	0.0000	0.0000	0.0000	0.0000
5.10	0.0148	0.0000	0.0000	0.0000	0.0000
5.13	0.0339	0.0002	0.0000	0.0000	0.0000
5.17	0.0495	0.0011	0.0000	0.0000	0.0000
5.20	0.0590	0.0044	0.0000	0.0000	0.0001
5.23	0.0675	0.0126	0.0001	0.0001	0.0004
5.27	0.0769	0.0237	0.0004	0.0002	0.0010
5.30	0.0879	0.0339	0.0009	0.0005	0.0017

- Case 26 Plot Simulation

Table 3 shows a simulation at time 5.17 s until 5.32 s. The label indicates the first monitor point that capable detects 5% concentration of methane gas. Monitor point 1 (MP 1) detects 5% concentration at time 5.20 s.

Table 3 Time taken for flammable gas detection

Time (s)	MP 1	MP 50	MP 61	MP 2	MP 72
5.17	0.0000	0.0000	0.0000	0.0000	0.0000
5.20	0.0001	0.0000	0.0000	0.0000	0.0000
5.23	0.0001	0.0000	0.0000	0.0000	0.0000
5.25	0.0002	0.0001	0.0000	0.0000	0.0000
5.27	0.0003	0.0001	0.0000	0.0000	0.0000
5.29	0.0004	0.0002	0.0000	0.0000	0.0000
5.30	0.0002	0.0001	0.0000	0.0000	0.0000
5.31	0.0006	0.0002	0.0000	0.0000	0.0000
5.31	0.0014	0.0006	0.0000	0.0000	0.0000
5.32	0.0028	0.0017	0.0000	0.0000	0.0000

- Case 31 Plot Simulation

Table 4 shows a simulation at time 5.30 s until 5.40 s. The label indicates the first monitor point that capable detects 5% concentration of methane gas. Monitor point 1 (MP 1) detects 5% concentration at time 5.32 s.

Table 4 Time taken for flammable gas detection

Time (s)	MP 1	MP 50	MP 61	MP 2	MP 13
5.30	0.0000	0.0000	0.0000	0.0000	0.0000
5.32	0.0001	0.0000	0.0000	0.0000	0.0000
5.33	0.0001	0.0000	0.0000	0.0000	0.0000
5.34	0.0001	0.0000	0.0000	0.0000	0.0000
5.35	0.0002	0.0000	0.0000	0.0000	0.0000
5.36	0.0003	0.0001	0.0000	0.0000	0.0000
5.37	0.0003	0.0001	0.0000	0.0000	0.0000
5.38	0.0005	0.0001	0.0000	0.0000	0.0000
5.39	0.0007	0.0002	0.0000	0.0000	0.0000
5.40	0.0012	0.0003	0.0000	0.0000	0.0000

- Case 32 Plot Simulation

Table 5 shows a simulation at time 4.99 s until 5.18 s. The label indicates the first monitor point that capable detects 5% concentration of methane gas. Monitor point 30 (MP 30) detects 5% concentration at time 5.01 s.

Table 5 Time taken for flammable gas detection

Time (s)	MP 30	MP 64	MP 53	MP 44	MP 33
4.99	0.0000	0.0000	0.0000	0.0000	0.0000
5.01	0.0001	0.0000	0.0000	0.0000	0.0000
5.04	0.0005	0.0000	0.0000	0.0000	0.0000
5.06	0.0037	0.0000	0.0000	0.0000	0.0000
5.08	0.0160	0.0000	0.0000	0.0000	0.0000
5.10	0.0324	0.0002	0.0000	0.0000	0.0000
5.12	0.0436	0.0018	0.0000	0.0000	0.0000
5.14	0.0523	0.0067	0.0000	0.0000	0.0000
5.16	0.0600	0.0146	0.0000	0.0000	0.0000
5.18	0.0679	0.0225	0.0000	0.0000	0.0000

The results in Table 2 - 5 shows the first MP that can detects the 5% concentration of methane gas. Table 2 and Table 5, MP 30 is the earliest monitor point that can detect 5% concentration meanwhile for Table 3 and Table 4, MP 1 is the earliest monitor point that can detect 5% concentration.

The time taken for the 5% concentration reached monitor points is different. MP 30 in Table 2 took 5.01 s, MP 1 in Table 3 took 5.20 s, MP 1 in Table 4 took 5.32 s and MP 30 in Table 5 took 5.01 s. The earliest time taken for MP 1 was 5.20 s and MP 30 were 5.01 s where the time difference between these two monitor points is 0.19 s. The location of MP 1 is (28, 5, 2) and MP 30 is (20.667, 5, 2) where the spacing of these monitor points is approximately 8 m which is more than the normal radius of the gas detector coverage. Thus, both monitor points are selected in this study.

C. The highest number of scenarios detected

Several scenarios were run based on those factors considered in this case such as wind speed, wind direction, leak rate and leak direction.

The monitor points that can detect almost all the scenarios is being chosen as the most strategic placement for the gas detector. Based on the monitor points case scenarios, it can be identified the highest number of scenarios detected. Based on the tabulated data in Table 6, MP50 has the highest number of scenarios detected and MP54 is the lowest number of gas detected. The chosen MP is based on all cases that can detect the flammable limit of methane gas.

Table 6 Monitor points detect the 5% methane concentration

Scenarios detected most	MP	Location of MP	The earliest detection time to 5% LEL (sec)
17	50	(28,6,2,) m	5.605
16	2	(30,5,2) m	5.713

Scenarios detected most	MP	Location of MP	The earliest detection time to 5% LEL (sec)
16	3	(32,5,3) m	6.052
16	61	(30,6,2) m	5.663
14	22	(9.33,5,2) m	5.703
14	72	(32,6,3) m	6.075
13	33	(11.33,5,2) m	5.587
13	44	(13.33,5,3) m	5.541
12	1	(28,5,2) m	5.585
11	13	(30,5,3) m	6.146
11	53	(18.67,6,2) m	5.431
11	64	(20.67,6,2) m	5.253
11	68	(11.33,3.5,2) m	5.622
9	30	(20.667,5,2) m	5.095

The green boxes in Table 6 indicate the selected monitor points for gas detector placement. MP 50 is selected because it has the highest number of scenarios detected, MP 1 and MP 30 are selected based on the worst-case identification and MP 64 is the nearest and the shortest time taken for the gas detector to detect flammable gas release.

IV. CONCLUSION

The study concludes that the approach applied meet all the objectives for the gas detector placement which will assist in improving the gas detector layout assessment. However, there are some recommendations are needed for further improvement which this study may proceed with the increasing number of simulations by using the input data collected from the plant. Before simulating all the cases, it is recommended to refer FERA study as a basis for the explosion assessment part. Besides that, the input data should be based on site data to get the most accurate results that applicable to all offshore facilities. In summary, the study proves that the placement of the gas detector based on the simple method as discussed is achievable and applicable to all facilities for onshore and offshore.

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