

Need for PRA in the Oil and Gas Industry

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Abstract: Probabilistic Risk Assessment (PRA) is widely used in the nuclear industry to assess the risk from hazards to nuclear power plants. This paper discusses the application of PRA methods to the oil and gas industry, and, specifically, to assessing production platform safety and optimizing levels of hydrocarbon production. Oil and gas platform safety can be analyzed with a focus on potential loss of life to platform workers from internal hazards such as uncontained liquid or gas hydrocarbon releases with subsequent ignition. Additionally, platform production capabilities can be analyzed with a focus on reducing production downtimes. PRA methods can be effectively utilized to identify both safety and operating issues for typical platform alignments, maintenance and testing frequencies, and prioritization of enhancements to platform operation.

Keywords: PRA, PSA, Oil and Gas, Production Platform

1. INTRODUCTION.

Probabilistic Risk Assessment (PRA) methodologies have been widely adopted and embraced by the nuclear power industry and the nuclear regulatory commission as an effective means of estimating the risk associated with operating nuclear power plants and with providing insights to the nuclear power plant response to hazards. Although the focus of nuclear power plant PRAs is primarily aimed at the core damage and release of fission products to the environment, the methodology can be applied to production risk and industrial (personnel) safety risk in both the nuclear industry and in other industries that operate large numbers of relatively complex facilities. This paper explores the potential for application of PRA methodology to the oil and gas industry, specifically to offshore hydrocarbon production facilities, with a focus on safety risk, environmental risk, and production risk. This paper also provides the framework for considering an integrated total platform risk assessment of each of these hazard types and consequences.

2. OIL AND GAS PLATFORM BACKGROUND

The oil and gas industry operates facilities on both land and sea to extract the hydrocarbons for storage and transport to market. The operations involve exploration, drilling, pumping, storing, and transporting the hydrocarbons. Each of these types of industrial operations entails risks associated with processing hydrocarbons.

The oil and gas industry operates hundreds of hydrocarbon production facilities worldwide. In general, major accidents are infrequent. The extent of local accidents that result in loss of life, environmental release of hydrocarbons, and loss of production is generally unknown to the greater public, since these events may not rise to the threshold of media attention. However, rarely major accidents do occur. A list of some of the most significant of these accidents [1] are listed below:

- A Blowout accident at Platform A offshore near Santa Barbara CA, resulted in a 100,000 barrel spill in 1969.
- The Pemex-operated Ixtoc I offshore well experienced a blowout, resulting in a 3 million barrel spill in 1979.
- The Alexander Kielland floating platform in the North Sea for off-duty workers capsized in 1980, resulting in 123 fatalities.

- The Ocean Ranger semi-submersible drilling rig sank off the coast of Newfoundland, Canada in 1982, resulting in 84 crew member fatalities.
- A blowout on the Enchova platform in the Campos Basin near Rio de Janeiro, Brazil caused an explosion and fire that resulted in dozens of fatalities in 1984.
- The Piper Alpha platform exploded and sank in the North Sea, resulting in 167 fatalities in 1988.
- An explosion on an offshore oil rig off the coast of Nigeria resulted in 13 fatalities and many more injuries in 1995.
- The P-36 offshore production platform sank off the coast of Rio de Janeiro five days after an explosion that killed 11 people. 10,000 barrels of fuel and crude spilled into the ocean in 2001.
- A fire destroyed the Mumbai High North Processing platform off India's west coast in 2005, resulting in loss of 15% of the country's production (123,000 barrels per day) and causing 12 fatalities.
- The Usumcinta rig collided with the Kab-101 platform off the coast of Mexico during stormy weather, resulting in 21 fatalities in 2007. The fatalities occurred when workers attempted to evacuate in life rafts.
- The West Atlas mobile drilling rig leaked oil and gas into the East Timor Sea near Australia, and later sank after a subsequent fire in 2009. The spill continued for months spilling millions of gallons of crude.
- An explosion and fire on the drilling rig Deepwater Horizon resulted in 11 fatalities and the spilling of roughly 5 million barrels into the Gulf of Mexico in 2010.
- A Venezuelan natural gas exploration rig sank in the Caribbean Sea in 2010.

The use of PRA methods is most effective for assessing low frequency, high consequence risk conditions.

3 PRA APPLICATION TO OIL AND GAS INDUSTRY

3.1. Hazards and Accidents

Oil and gas facilities are subject to hazards that impact the safety of the platform and personnel, environmental containment of the hydrocarbons, and production operations. Each of these hazards shares some underlying characteristic that can be assessed and managed beneficially for each hazard, although unique aspects of each type of hazard also exists. For example, the risk of loss of piping integrity for production piping is hazardous to both personnel and platform safety, environmental containment, and production, but the risk of loss of an operating pump may only impact production risk. Each individual hazard type is briefly described below. Note that the hazards can be classified as either "internal" (due to conditions or evolutions related to the processing operation) or "external" (due to weather, tsunami, earthquake, or other event that affects the processing operation from the environment).

3.1.1. Personnel Safety

Industrial accidents that result in injury or fatality occur during platform operations and are the result of equipment problems and/or human performance problems. Hazards include loss of hydrocarbon containment and subsequent ignition which can result in injuries or fatalities local to the source of hydrocarbon release. This type of risk has lower consequences assuming that mitigation strategies succeed in isolating or terminating the hydrocarbon release and/or ignition. Should mitigation fail to contain the release, the accident can result in higher loss of life or loss of platform, both are high consequence events. Typical safety hazards are as follows:

1. Hydrocarbon release and subsequent ignition (internal hazard)
2. Industrial hazards due to rotating equipment, systems under pressure, human error during maintenance/operation, etc. (internal hazards)
3. Severe weather events such as hurricanes/storms/rough seas (external hazard)

4. Seismic events (external hazard)
5. Transportation accidents resulting in fire/explosion (external hazard)

3.1.2. Environmental Impact

Accidents that cause hydrocarbon release to the environment result in fatalities, loss of production, and a decrease in public perception of the safety of the oil and gas industry. These events can be difficult to terminate (as seen during the Deepwater Horizon oil spill in the gulf of Mexico) and the economic impact can be significant if legal action is pursued against the oil and gas company and/or increases in regulation result from the event. Recent estimates put the cost of the Deepwater Horizon incident at over 40 billion dollars. Typical accident types are as follows:

1. Oil or gas well blowout
2. Pressure boundary ruptures in production facility
3. Transportation accident resulting in loss of crude

3.1.3. Production

Events that cause a loss of hydrocarbon production results in economic impact to the oil and gas company and significant losses can impact the oil and gas market of a country or the world as a whole. The following types of hazards impact production:

1. Equipment failures and human error leading to platform shutdown
2. Severe weather resulting in platform shutdown
3. Seismic events resulting in loss of well integrity
4. Transportation accidents

3.2. Risk Assessments

Current risk assessment methods employed by the oil and gas industry include qualitative assessment and quantitative risk assessments provided for safety accident risk (those that involve potential loss of life and loss of the platform facility). Some examples of existing tools that are applied to the industry are Layer-of-Protection Analysis (LOPA) [2] and Quantitative Risk Assessment (QRA) [4]. These tools are used and provide reasonable assessments of the risks associated with the safety aspects of platform operation:

- Layer of Protection Analysis: The LOPA combines the qualitative with some amount of quantitative approach to risk assessment. It identifies operations, practices, systems, and processes that do not have adequate safeguards and helps in deciding the layers of protection required for a process. It focuses on the most critical safety systems. This approach is essentially equivalent to the “Defense in Depth” approach in the nuclear industry.
- Quantitative Risk Assessment: A QRA is used to provide a fully quantitative risk assessment. This type of assessment is currently used to quantify safety risk of the oil platforms. It combines the frequency of the hazard with its consequences and provides a numerical representation of the risk generated via mathematical models of the hazard and consequences.

These types of assessments are generally effective at assessing the safety and accident risk for oil and gas platforms. However, given the common cause events that result in the safety, environmental, and production risk, as seen by the common impacts from the hazards described in Section 3.1, benefit can be gained from expanding the analysis to include a comprehensive, total integrated assessment of the risk to personnel and platform safety, risk of environmental release, and risk of production losses during platform operation by focusing on the assessment of the common hazards and accident types.

3.2.1. Personnel Safety

Significant focus is already given to personnel safety, but safety improvements are primarily focused on reducing the hazard and initiating events with relatively little focus on reducing the consequences of the accidents. Evaluation of the consequences beyond what is currently performed in the QRA

would provide additional risk reduction benefit. An example of consequence reduction would be evaluating the distribution of personnel on the platforms and assessing strategy for reducing exposure to platform locations that carry more risk. This assessment can be provided by utilizing the maintenance schedule for internal equipment hazards to determine the risk of the platform configuration and then assessing the risk of hydrocarbon release and ignition that occurs during maintenance for each area of the platform. Personnel access and travel through the areas with elevated risk could be restricted. An integrated schedule tool/risk model can provide this information to the operating crew/maintenance staff prior to beginning maintenance activities on the platform.

Similarly, external hazards such as severe weather events and rough seas can have an impact on safety risk. The benefit of a PRA methodology and integrated tool would be to provide insights into combinations of internal and external events to assist in operations assessment of the personnel safety risk. This assessment could manifest itself as a deferral of maintenance activities as necessary to maintain pre-defined personnel safety risk levels that would be set in accordance with the company's safety goals.

3.2.2. Environmental Impact

Environmental impact events merit a risk assessment due to the high economic cost, potential for legal action, and negative public perception of these events. Often these events occur concurrent with personnel fatalities as well as loss of production [1] when originating from the platform. Other environmental impact events occur during transportation accidents.

One contributing cause to the Deepwater Horizon incident [5] cited weaknesses in the risk assessment of the annulus cement barrier which might have prevented the hydrocarbons from entering the wellbore annulus. Performing a risk assessment using an integrated model tool for this portion of the production operation may have identified mitigating features that could have been taken to prevent the loss of containment and also raised awareness of the risks of the operation, potentially allowing identification of the incident prior to events reaching a critical point in the accident timeline. An additional cause was identified as a misinterpretation of pressure test data. The interpretation may have been influenced by the lack of risk assessment which would have reinforced the awareness of the risks of the operation. A third contributing cause was identified that the venting of the leaking hydrocarbons through the mud gas separator vent line and subsequent communication of the hydrocarbons from electrically qualified areas through the HVAC system to unqualified areas created the potential for ignition. Each of these causes could have been prevented by performing a risk assessment of the hydrocarbon flow paths when well integrity is lost.

3.2.3. Production

The benefits of a production risk assessment are obvious; increased production has a beneficial impact on the oil and Gas Company's financial health as well as a benefit to the world markets by increasing supply. Application of a risk assessment to the production equipment, operational practices, and maintenance practices of the platform can provide insights into vulnerabilities that may result in a loss of production. The results of the assessment can be used to optimize platform operation and maintenance with goal of increasing production. The decrease in production loss risk would be balanced against the safety risk and the environmental risk.

3.3. Optimization

Given that industry currently treats these risks using established methods, the natural question that occurs is "how does the application of these methods and tools result in significant benefit beyond what is currently performed?" The answer lies in the ability to account for these hazards and goals with a combined assessment and with a risk assessment tool that can be used to understand the assessment. Because safety risk is typically the top priority for industrial facilities, improvements in safety can have a negative impact on production risk. Although this is the prudent way to approach

industrial operations involving injury or fatality risk, the two do not necessarily have to be inversely related; the benefit of a combined assessment and tool would allow the oil and gas company to meet their safety goals and environmental impact goals while providing the ability to assess improvements that also decrease loss of production risks. At the very least, the integrated assessment and tool can be used to evaluate multiple options for decreasing the risk associated with safety and environmental impact while not increasing the risk of loss of production. This combined approach offers a best-of-all worlds approach to platform operation.

3.4. Scalability and Fleet Benefit

The oil and gas industry operates hundreds of offshore production facilities. Although there is some unique design and operating characteristics of each of these facilities, the generic approach using PRA methods and using an integrated model tool can be effectively scaled and applied to a fleet of facilities with much less effort than that needed to develop the first risk model. A comparison of results between platform models may yield additional platform-specific insights that general safety studies may not identify. This would benefit the operating crew by providing specific risk assessment information rather than providing general rules or strategies for reducing or mitigating risk associated with platform safety, environmental containment, and production loss.

4. CONCLUSION

This paper has provided an argument for application of a combined hazard and consequence risk assessment to offshore oil and gas platform operation. The combined assessment would focus on personnel safety, environmental containment of hydrocarbons, and risk of loss of platform hydrocarbon production. PRA methodology and tools can be effectively utilized to provide insights to all aspects of platform operation and provide significant global fleet benefit when applied across similar platforms.

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