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Evaluating generated risk event effect neutralization as a new mitigation strategy tool in the upstream industry

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Abstract

The upstream industry uses diverse risk mitigation approaches to mitigate eventual failures within its facilities. Yet, these approaches could not avert major accidents, on different scales, from happening as they negatively affect the industry. The purpose of this paper is to assess Generated Risk Event Effect Neutralization (GREEN) as a new tool to select suitable risk mitigation approach to prevent prospective failures in upstream industry. More than 200 hundred major accidents in the industry underwent GREEN evaluation and compared with existing risk mitigation approaches used in to mitigate eventual failures. Kuwait’s’ Mina Al-Ahmadi explosion was chosen as a case study to apply GREEN. The results of GREEN analyses were compared to both petroleum industry’s standards and best practices, as well as the evaluation from the design team at Kuwait’s Mina Al-Ahmadi to validate the result.

Keywords: Risk mitigation; Upstream industry; GREEN; Accidents

1. Introduction

The increasing global demand for petroleum is the driving mechanism for the petroleum companies to continuously upgrade their facilities and implement the latest technological advancements in equipment, computerized software, and synchronized human-system interaction [1]. Government agencies and professional societies guide the upstream industry with the best practices and regulatory guideline, to assure safe working environment and to administer the operations’ management [1]. Consequently, the industry utilizes a wide range of risk assessment tools to mitigate potential operational risks. Failure Mode and Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Bow Tie Analysis, What–If Analysis, Hazard and Operability analysis...
(HAZOP), and Layer of Protection Analysis (LOPA) are the most widespread tools used in the oil and gas industry. These meticulous tools evaluate potential risks and try to sustain them within tolerable limits [2][3][4].

The purpose of this paper is to evaluate Generated Risk Event Effect Neutralization (GREEN) as a new tool to aid, both engineers and managers, in choosing suitable risk mitigation approach. GREEN will assist in exploring different mitigation approaches and their competences in averting prospective failures in the upstream industry. In order to validate the results of GREEN, more than two hundred major accidents were selected and underwent GREEN evaluation. The origin of the failures was electro-mechanical, material failure, and design flaws. The causes of the accidents were validated by accident report. Thus, GREEN evaluation was associated with existing risk mitigation approaches used to contain prospective failures and their consequences. In addition, upstream industry’s professionals were consulted to validate both GREEN and industry’s risk mitigation approaches and best precise as foundation of rationalization.

These thorough systems, to name some, assess prospective risks and try to sustain them within allowable limits [2][3][4]. Yet, with rigorous techniques and risk mitigation tools utilized in the upstream industry, major accidents occur with catastrophic consequences affecting the environment, society and petroleum industry’s stakeholders. Accordingly, the need assess the conceivable risk mitigation approach is necessary to aid, both engineers and decision makers, to choose the optimal risk mitigation strategy. Hence, Generated Risk Event Effect Neutralization (GREEN) is an innovative will assist in exploring different mitigation approaches and their capabilities in preventing potential failures in the upstream industry.

2. The Generated Risk Event Effect Neutralization method (GREEN)

The Generated Risk Event Effect Neutralization method (GREEN) is a risk mitigation approach-selecting tool. The method, following Risk in Early Design (RED), developed by Dr. Grantham and her team identifies and selects the dominating and optimal risk mitigation strategy [5]. Hence, GREEN matrices define possible mitigation strategies where these matrices include “information on potential failure modes and their parameters, parameters that have been changed by mitigation strategies, and the likelihood and consequence changes for a given mitigation strategy” [6]. Figure 1 illustrates the overall GREEN process of selecting the most common and dominating risk mitigation strategy to potential failures (FS). The result of the functional model and RED analysis are the base for both determining the possible mitigation strategies and evaluating the most common strategy to fit the system, respectively. Based on the created matrices linking the failure modes to parameters (FP) and the parameters to mitigation strategies (PS) then they are multiplied together to create the Failure Mode-Mitigation strategy matrix (FP x PS = FS). This matrix illustrate potential failure modes, applicable mitigation strategy, and the frequency of how many time this strategy has been implemented to contain the corresponding failure mode [6].
In order to explore the validity of GREEN, the tool will be applied to a case study in the upstream industry. The results of the analysis will be validated with industry recommended practices and confirmed by industry’s professionals.

3. Applying GREEN in the upstream industry

For GREEN to effective in selecting the appropriate risk mitigation strategies, historical failure database imbedded in the Risk in Early Design (RED) software are cataloged to identify potential failure modes. More than two hundred accidents caused by electro-mechanical failures in the industry underwent GREEN evaluation to identify both failure modes and corresponding optimum risk reduction and mitigation strategies. The process is a series of steps that links the mitigation strategies with failure modes, compares the potential strategies, and chooses the most common strategies, by lowering both the likelihood and consequence of potential failure modes. An accident due to electro-mechanical failure from the upstream industry was selected to validate the consistency of GREEN analysis. The method utilizes the analysis of Risk in Early Design (RED) software and indicates the most common mitigation strategy, accordingly. The first step in performing an accurate RED analysis is selecting the functions performed by components of the system. These functions can be selected from a list of “electromechanical functions” cataloged in the RED software tool. Consequently, GREEN will identify the recommended optimal mitigation strategies to be applied for the selected process.

3.1. Kuwait’s Mina Al-Ahmadi Accident

Kuwait’s Mina A-Ahmadi is the largest of three crude oil refinery with a refining capacity over 460,000 barrel per day [7]. The refinery produces Benzene, jet fuel, and diesel for both domestic and export markets. In June 25, 2000, while maintenance crew were attempting to control a gas leak from a Liquefied Natural Gas (LNG) pipeline at the refinery, an explosion occurred and destroyed the entire facility. The explosion killed five workers near-by, more than fifty workers on site were injured and financial losses of more than $840 million; both from production loss and revamping the facility [7]. The cause of the gas leak was due to several reasons; stress corrosion cracking caused the pipeline to burst [5][8]. The fluctuation in flow of the liquified natural gas due to compressors’ cyclic pumping resulted in high-cycle fatigue’s superimposed the corrosion in the pipeline [9]. In addition, stresscorrosion, the result of the sour nature of the natural gas due to the existence of Carbon dioxide, Hydrogen Sulfide, and other corrosive substances, negatively impacted the overall mechanical integrity of the pipeline [8].

In order to Apply GREEN for the most common risk mitigation approach, the functionality of the pipeline has been analyzed by Risk in Early Design (RED) software. As a result, and utilizing GREEN Matrices [6], the potential mitigation stratigies were determined for this case study. The results of GREEN anaysis identified 20 mitigation strategies for high cycle fatigue, 23 for corrosion fatigue, and 22 for stress carrion, respectively. Table 1 illustrates the collection of mitigation strategies presented by the FS matrix with the number of occurrences, in addition the likelihood and consequence changes provided from the SC matrix [6].

Fig.3.A Benzene unit destroyed during the explosion (KNPC, 2014)
Table 1. GREEN results for high cycle fatigue new popularity, likelihood and consequence

| Strategy               | Popularity | New Likelihood | New Consequence |
|------------------------|------------|----------------|-----------------|
| Change natural frequency | 0         | 5              | <5              |
| Condition Material     | 1         | 5              | <5              |
| Condition Part         | 1         | 5              | <5              |
| Convert Material       | 3         | 4.8            | 4.8             |
| Convert Part           | 1         | 5              | 4.9             |
| Couple Part            | 0         | 5              | <5              |
| Decrease Motion        | 0         | 5              | <5              |
| Decrease Power Assist  | 0         | 5              | <5              |
| Import Lubricant       | 0         | 5              | <5              |
| Import Material        | 0         | 5              | <5              |
| Import Part            | 0         | 5              | <5              |
| Import Stress          | 0         | 5              | <5              |
| Increase Control       | 1         | <5             | <5              |
| Increase Flow          | 0         | 5              | <5              |
| Remove Part            | 0         | <5             | <5              |
| Secure Part            | 1         | <5             | <5              |
| Separate Contaminant   | 0         | 5              | <5              |
| Shape Part             | 5         | 5              | <5              |
| Stabilize Process      | 0         | 5              | <5              |
| Stop Process           | 0         | 5              | <5              |

4. Conclusion

As the upstream industry applies different risk assessment and strategy selection tools to mitigate potential failures, accidents on different scales continue to occur as they negatively impact the industry. Generated Risk Event Effect Neutralization (GREEN) analysis was utilized to examine potential risk mitigation strategies upstream industry. The analysis successfully identified potential failure modes for different major accidents with different causes of failures and the possible strategies to control them. The analysis was successful in capturing the failure modes that caused catastrophes in two hundred major accidents, in addition to potential risk mitigation strategies to prevent similar future accidents. GREEN is advantageous in producing a list of prelude risk assessment based on catalogued historical product failure record, and their corresponding control strategies. The tool can assist novice engineers and decision makers in the upstream industry in recognizing potential failure modes in the process system and how, to accurately, mitigate their likelihood and consequence; especially in the design conceptual design stages.

As a future work, the tool will address the human factor aspect in the industry due to its importance with the merging complex technologies. The close interaction between human and machines in a very volatile process environment makes it necessary to consider human-system integration and human factors part of the overall system design. Hence, this consecration will look into risk from different perspectives resulting in design safety and operating efficiency.
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