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Dynamic Safety Analysis in CNG Stations Using a Hybrid Fault Tree Approach and Bayesian Network Techniques

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Abstract

Introduction: The safety of CNG stations is important because of their location in urban areas, as well as to prevent accidents and to protect the safety of personnel, property, and environment. An event occurrence analysis with probability updating is the key to dynamic safety analysis.

Material and Methods: In this study, the Failure Modes and Effects Analysis (FMEA) technique was used to determine the hazards of the study unit, the method of analyzing. After determining the hazards with high risk, the Bayesian fault tree analysis (BFTA) method was used to determine the effective causes of events occurrence and the type of possible relationships among them.

Results: First, the phase of hazards identification, 16 Hazardous equipment were identified. Then the Risk Priority Number for the identified equipment was calculated. The results showed that the dispenser system had the highest risk priority number and was identified as the most critical equipment. According to this, the dispenser gas leakage (as the top event) was selected in this study. Then, the analysis of the dispenser gas leakage, using BFTA method identified 56 main causes, including 17 intermediate events and 39 basic events. Finally, cracking and corrosion of the dispenser hose were determined the most effective factor in the occurrence of the top event. The probability of occurrence of the top event based on FTA and BFTA analysis was calculated 9.67×10-2 and 9.11 × 10-2, respectively.

Conclusion: The result of the study that by employing the Bayesian Network, can create a useful guideline to determine the relationship between the occurrence causes of the top event. This provides an assessment of the effectiveness of preventive measures before using them.

Keywords: Dynamic Safety, Bayesian Network, Fault Tree Analysis, FMEA

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1.Introduction

Natural gas is a clean, economical, and environmentally beneficial energy source with a lot of uses in today's world [1]. It is primarily composed of methane, which is highly flammable and explosive. A mixture of 4.5 to 16.5 percent of methane in the air is flammable and explosive, and its ignition energy is 280 micro Joules. Methane can be used as a compressed fuel for vehicles [2]. Due to the CNG stations locations, they are potentially dangerous where as have a high safety importance. As a result, the safety of people has been a major concern since the start of the commercial use of compressed natural gas as a new type of vehicle fuel [2, 3]. Having considered these, safety analysis is very important at CNG facilities. An event occurrence analysis with probability updating is the key to dynamic safety analysis. The purpose of the current study is a comprehensive and dynamic safety analysis of CNG stations.

2. Material and Methods

In this study, the failure modes and effect the hazards of the study unit. This technique provides a very powerful and effective analytical tool that identifies and counts process weaknesses [4]. Using this method, the Risk Priority Number (RPN) of identified hazards was calculated and for the risk with the highest risk priority number, the top event was determined. FTA technique was applied to identify and analysis to occurrence causes of the top event. FTA is a logical and hierarchical model that shows the occurrence of the undesired accident by combining the intermediate events and basic events. Commonly, the undesired accident was regarded as the top event of the fault tree. In FTA, the logical "AND" and "OR" gateways were applied to show the relationship among events and their causes [5]. Then, Bayesian Fault Tree Analysis method (BFTA) was used to determine the effective causes of events occurrence and the type of their possible relationships and the dynamics of risk analysis,. Bayesian network model shows the severity of the quantitative relation between variables, allowing the probabilities to be updated by accessing new information [6].

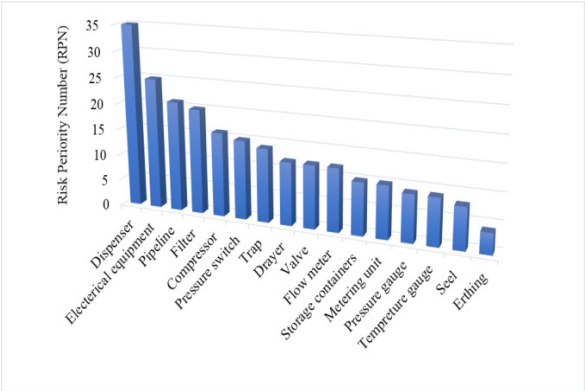

Fig. 1. CNG Station Equipment Ranking by Risk Priority Number.

It is important to identify the most effective basic events in systems safety analysis. To this end, using updated basic events probability values lonely to determine the most effective basic events may cause errors in selecting these events. To avoid this, the ratio of variation (RoV) can be used to select the most effective basic events [7].

3. Results and Discussion

In the phase of hazards identification, 16 hazardous equipment risk were identified. Then the Risk Priority Number for the identified equipment was calculated and was shown in Figure 1. RPN for all hazard sources in CNG stations. As seen in this figure, the dispenser system had the highest risk priority number and was identified as the most critical equipment. Considering all above, the dispenser gas leakage (as the top event) was selected in this study.

Dispenser gas leakage (top event) Fault Tree was assessed and was shown in Figure 2. Identification of the main causes of dispenser gas leakage system were collected through direct observations, interviews with experts, and review of documents and operational maps. In the present study, the occurrence probability of events was obtained from the databases such as OREDA and the experts' opinion in this field.

Although, the FTA method provides a powerful modelling of the basic causes leading to the top event, it has many important limitations, the most

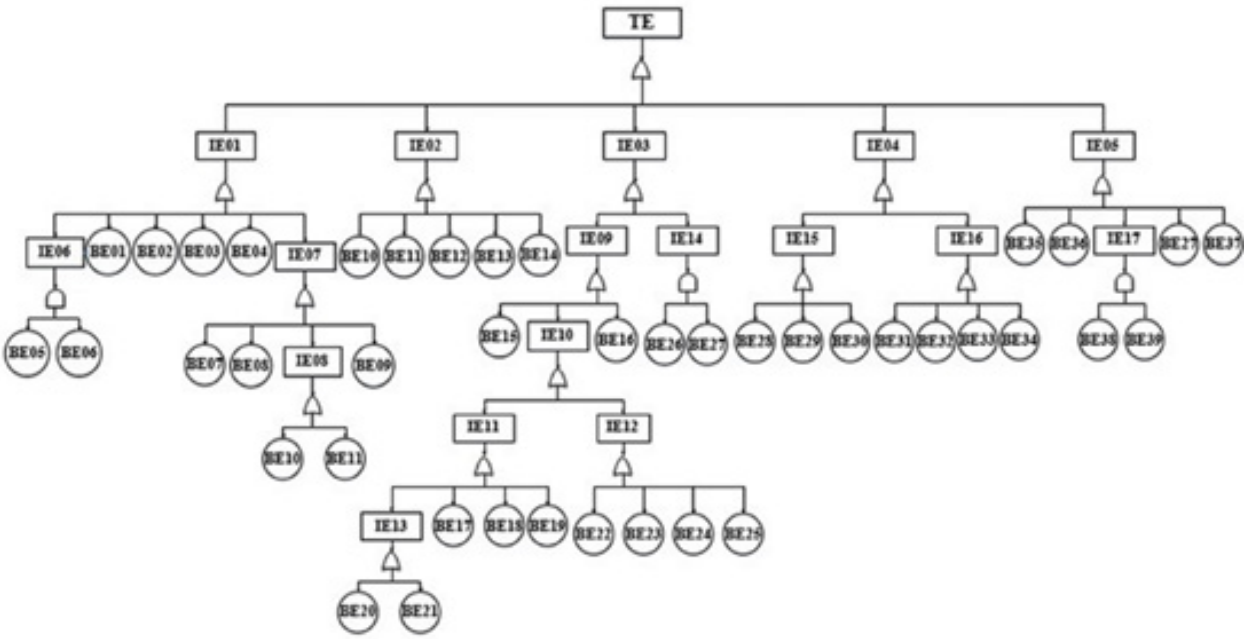

Fig. 2. The fault tree of the dispenser gas leakage.

important of which are static and inability to adapt dynamic events, that nowadays this issue has become significantly more important in the safety analysis of process industries (6). In the currently study, in order to eliminate the limitations of the FTA, Bayesian Fault Tree Analysis method (BFTA(was used. The analysis of the dispenser gas leakage, using BFTA was identified 56 main causes, including 17 intermediate events and 39 basic events.

One feature of the BFTA is deductive reasoning to predict the top event occurrence probability (8). The FTA results was cleared the occurrence probability of the top event was 9.67×10-2 and the results of the BFTA model was indicated the occurrence probability of the top event 9.11×10-2, which is lower than the value was obtained from the FTA model. This is due to the consideration of a conditional dependency among basic events in BFTA, which cannot be considered in FTA.

Despite to the deductive reasoning, BFTA model has the capability of inductive reasoning, which is very important in dynamic safety analysis (8). Because, allowing the probabilities to be updated by accessing new information. In order to update the BFTA constructed model, the top node (Dispenser gas leakage) was taken into account as evidence and the prior and posterior probabilities of all the basic and intermediate events were updated. In order to identify the most effective basic events in the top event occurance prior and posterior probabilities of basic events were comprised that was shown in Figure 3.

RoV in the basic events failure probability of the dispenser gas leakage incident was shown in Figure 4.

In the present study, comparison of Figure 3 (Comparison between the prior and posterior probabilities of basic events) with Figure 4 (RoV) were concluded to different results. In this research, the probability of cracking and corrosion dispenser hose (BE13) significantly increased from 1.24×10-2 to 1.36×10-1 (the ratio of variation (RoV) = 9.96), as the most effective basic event contributors to dispenser gas leakage.

4. Conclusion

The present study was demonstrated the application of a comprehensive and a hybrid to the CNG station safety analysis using FMEA, FTA, and BFTA techniques. Accordingly, the dispenser gas leakage was identified as the most critical hazard

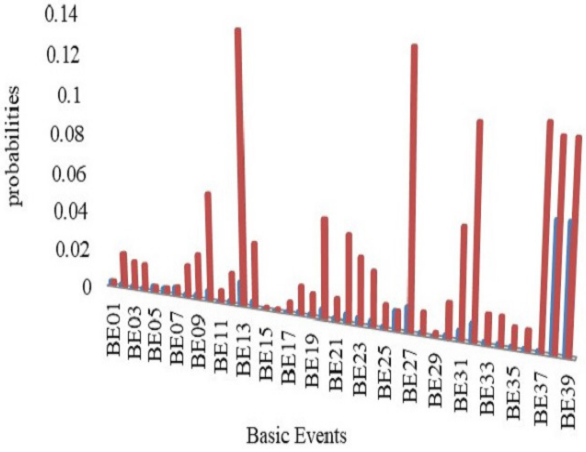

Fig. 3. Comparison between the prior and posterior probabilities of basic events.

(top event) in CNG stations. BFTA method was used to identify the main causes of the dispenser gas leakage occurrence probability, update and the relationship among the causes of the top event and the most effective factor in the occurrence of the top event. Based on BFTA analysis, crack and corrosion of the hose were identified as the most effective factor in the dispenser gas leakage. The results of the study was indicated that identification of critical basic events should be carried out based on the ratio of variation of probabilities instead of only focusing on prior or posterior probabilities.

5. References

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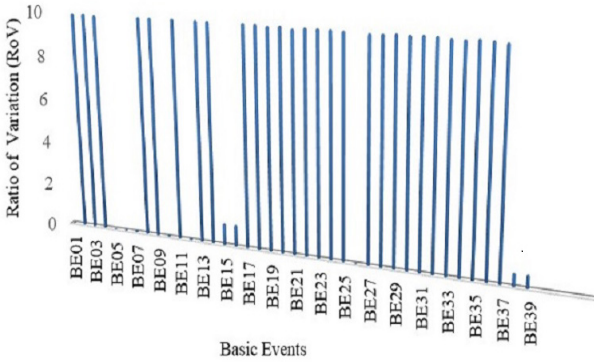

Fig. 4. RoV of the basic events probabilities.