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Research Article

Reliability Quantitative Risk Assessment in Engineering System using Fuzzy Event Tree Analysis

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Abstract

Quantitative risk assessment and reliability is most famous approach used for precise the values of possible outcomes of initiating event. The Event Tree Analysis (ETA) is a graphical logic model for assessing probability of an accident, ETA is either a preincident or a post incident application. In this paper new model proposed for reliability quantitative risk assessment using event tree analysis with a fuzzy sets approach for solve problem of uncertainty and imprecise of outcomes and risk in the chemical industry. The results got by new model is more precise and more powerful to deal with uncertainty in results and helpful for reliability quantitative risk assessment.

Keywords: *Quantitative Risk Analysis, Event Tree Analysis, Reliability, Fuzzy sets.*

1. Introduction

Reliability of system is the ability to operate under designated operating conditions for a designated period of time or number of cycles through a probability. The Improve of reliability for prolonging the life of the item based on two steps essential, on the one hand, study reliability issues and on the other hand, estimate and reduce the failure rate (Mohammad**,** 1999; Dasgupta, 1991). Two approaches for Risk analysis, which can be qualitatively and quantitatively. The qualitative approach used when there is a source of danger, and when there are no safeguards against exposure of the hazard, and then there is a possibility of loss or injury. In complex engineering systems, there are often safeguarded against exposure of hazards for maximizing the level of safeguards, and minimize the level of risk. The quantitative risk analysis is the approach concerned with this study. Since quantitative risk analysis involves estimation of the degree or probability of loss, risk analysis is fundamentally intertwined with the concept of probability of occurrence of hazards (Mohammad**,** 1999).
Quantitative Risk Assessment (QRA) for objective to estimates the outcome event probability of event tree and uses crisp probabilities of events to estimate the outcome event probability or frequency (Kenarangui, 1991; Lees, 2005; Ferdous, 2006).Whereas qualitative risk analysis identifies the possible outcome of initiating event. The classifications of uncertainty, aleatory and epistemic uncertainties are the major classes (Thacker and Huyse, 2003; Adam, 2010). QRA in industry had used to analyze hazards, qualitative methods suffer from a number of limitations. The resultant uncertainty combined with the natural or statistical variability within the often scarce information that further available complicates scenario predictions and comparisons (Refaul, 2011).

Nowadays, several techniques and mathematical models of risk prediction have been developed. These include such as, Process Hazard Analysis (PHA), Layers Of Protection Analysis (LOPA) and Quantitative Risk Assessment (QRA). The latter is a rigorous and advanced approach to an essential and necessary for a good estimate industry safer and turns and risk management. This approach is mainly to identify potential or representative accident scenarios to estimate their frequency and analyze their consequences, by means of risk analysis methods (HAZOP, Fault Tree (FT), Event Tree Analysis (ETA), and mathematical models effects and vulnerability (Ayyub and Klir, 2006. Xiaomin,2012, Mercurio, 2009). Event trees used to obtain quantitative estimates of the probability of the consequences (Mariana,2001). The reliability in engineering systems is purpose of this study using fuzzy logic methods (Lees, 2005; Ding, 2010; Ireson**,** 1988). Reliability analysis of high voltage transmission systems (Ohba et al., 1984; Epstein**,** 2005; Gupta, 2007; Yang, 2007), and emergency response in the event of chemical hazard or spills (Raman, 2004; Lu and Zhang, 2007).

Fuzzy sets used to analyze event tree by different method where in this study fuzzy using Sugeno method and event tree analysis is the new model proposed to deal with the uncertainty of the consequence scenarios (Rasool, 1991. Michael, 2012). Sugeno method proposed for solving uncertainty and imprecise the value of risk and evaluate the safety of the system.

2. Fuzzy Event Tree Analysis

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2.1 Event Tree Analysis ETA

The event tree analysis is a graphical logic model to identify and quantify the possible outcomes of an initiating event. ETA is based on binary logic, in which an event has or has not happened and it is the analysis of the consequences arising from a failure or undesired event. The ETA is either a precedent application, or a post incident application which the precedent application examines the systems in place that would prevent incident precursors from developing into the incidents. The event tree analysis of such a system is often sufficient for the purposes of estimating the safety of the system. The post incident application is used to identify incident outcomes. An event tree is a visual representation of all the events which can occur in a system, with a precise mathematical representation associated with it. ET is also extended to include various exposure scenarios that affect the estimated magnitude of consequences (CCPS, 2000; Bowles and McClelland, 2000).

Quantification of the event tree diagram helps in predicting the frequency of each of the outcomes. The outcome event consequences, usually expressed in terms of fatalities, are then combined with the frequency of occurrence to produce an F-N curve to help assess the acceptability of the response to hazards (Andrews and Dunnett, 2000). Risk analysis for answer to the following questions (Kaplan and Garrick, 1981):

a) What can go wrong that could lead to an outcome of hazard exposure?
b) How likely is this to happen?
c) If it happens, what consequences are expected?

The answer of the first question by defines a list of outcomes. The likelihood of these scenarios should be estimated as the answer of the second question**,** and the consequence of each scenario should be described also as the answer of the third question (Mohammad**,** 1999)**.** Therefore, risk can be defined, quantitatively, as the following set of triplets:

R = (Si, Pi, Ci) (1)

i = l, 2. . . n, Where S is a scenario of events that lead to hazard exposure, P is the probability of scenario i**,** and C is the consequence of scenario I, where the ETA gave the best results for answer the three questions precedents.

2.2 Fuzzy Set Theory FS

2.1.1 Fuzzy Sets FS

Fuzzy set theory deal with mathematically model information uncertainties and the theory has been developed and applied in a number of real world applications (Dawson, 1994; Drake, 1994; Refaul, 2009). This section briefly reviews the concepts of fuzzy sets, fuzzy numbers, fuzzy aggregation, fuzzy reliability, and fuzzification technique (Huang.2001; Zadeh, 1965. David, 2001)The utility of fuzzy sets lies in their ability to model uncertain or ambiguous data, FS is important to observe that there is an intimate connection between Fuzziness and Complexity. Fuzzy sets provide means to model the uncertainty associated with vagueness, imprecision, and lack of information regarding a problem or a plant, etc (Dubois, 1980, Zadeh, 1978; Hartford,2004).The uncertainty is found to arise from ignorance, from chance and randomness, due to lack of knowledge, from vagueness. (Canos, 2008; R. Nait-Said,2008,2009; Bouchon et al, 1995; Radim Bris, 2013).

2.2.2 Fuzzy Numbers

The membership function $\mu_{\tilde{A}}(x)$ has the following characteristics (Dubois & Prade 1978). The membership function of the number $\tilde{A}$ can be expressed as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} \mu_{\tilde{A}}^{L}(x), & a \le x \le b \\ 1, & b \le x \le c \\ \mu_{\tilde{A}}^{R}(x), & c \le x \le d \end{cases} \quad (2)$$

$$\mu_{\tilde{A}}^{L}(x) = \frac{x-a}{b-a} \quad (3)$$

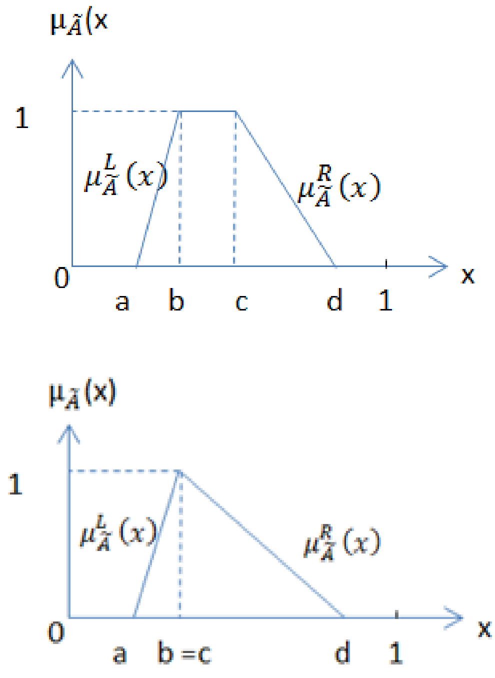


Figure.1 Trapezoidal and triangular fuzzy numbers

2.2.3 Fuzzy inference system FIS

Sugeno method is most commonly used fuzzy inference method (sugeno,1985; Guh, 2008; Wang, 2006, 2009). A typical rule in sugeno fuzzy model has the form, if input 1=x and input 2 =y, then output

z= ax+by+c (4)

The final output of the system is weighted average of all the rule output which is given as:

$$\text{Final output} = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i} \quad (5)$$

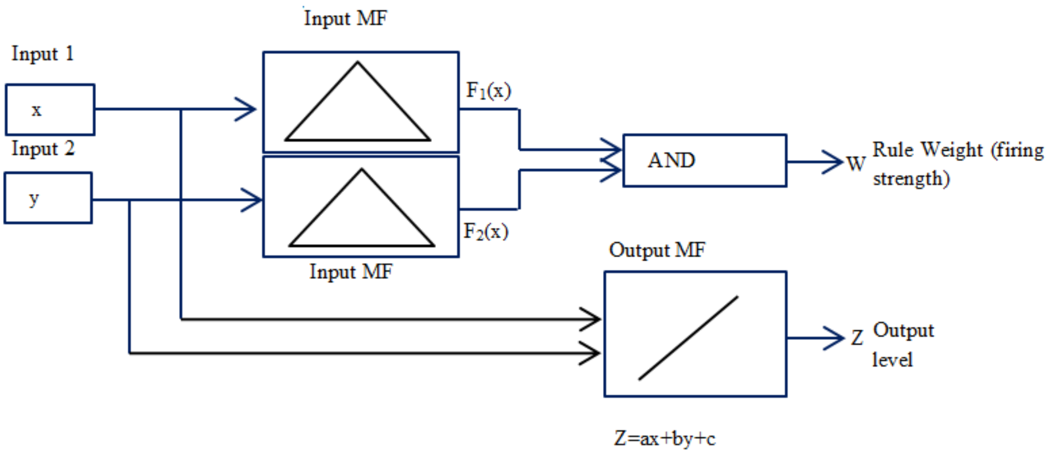


Figure.2 Sugeno rule operates diagram.

A FIS with five functional block described in Figure.3.

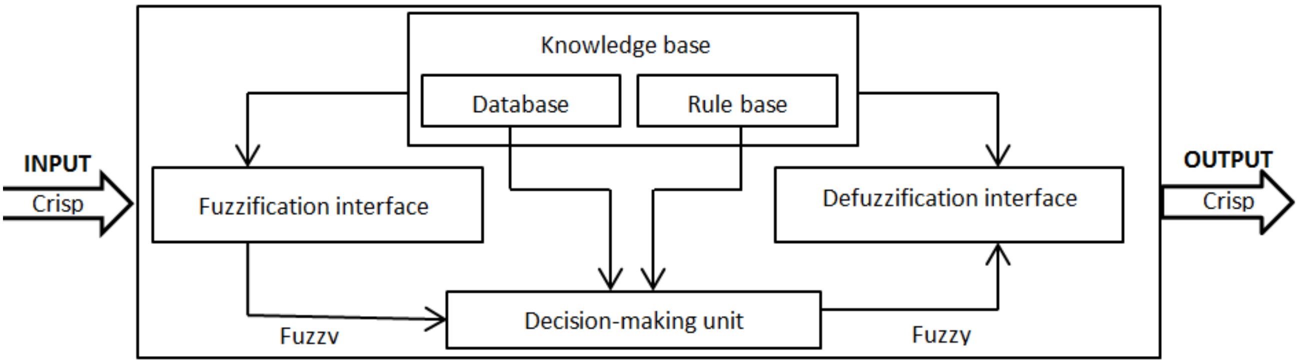
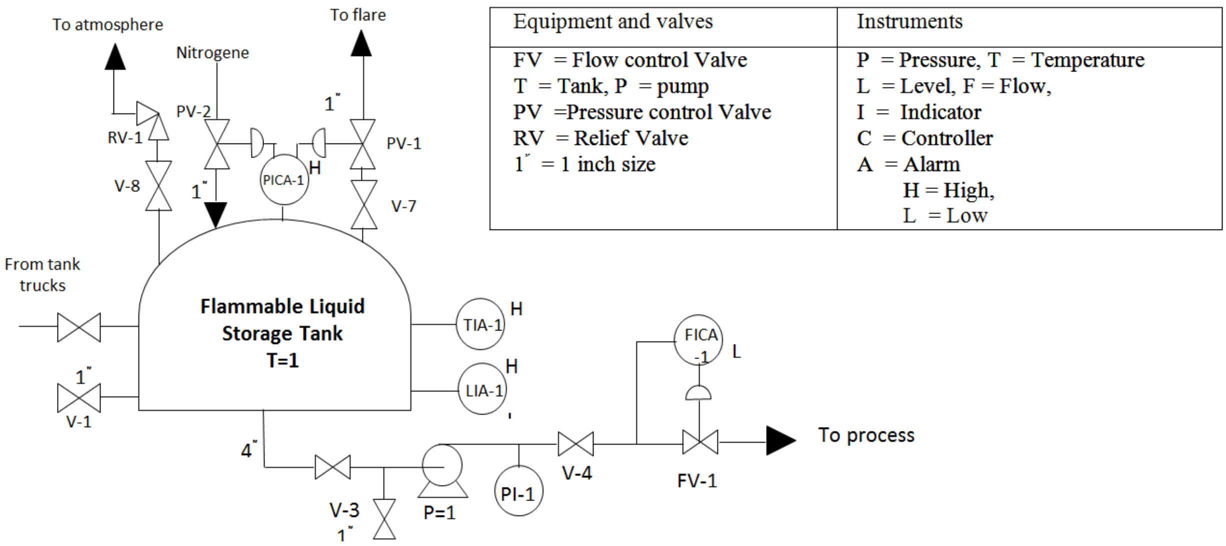


Figure.3 Fuzzy inference system



Equipment and valves	Instruments
FV = Flow control Valve T = Tank, P = pump PV =Pressure control Valve RV = Relief Valve 1˝ = 1 inch size	P = Pressure, T = Temperature L = Level, F = Flow, I = Indicator C = Controller A = Alarm H = High, L = Low

Figure.4 Flammables liquid storage tank.

3. Case study

The storage tank is designed to hold a flammable liquid under slight nitrogen positive pressure under controls pressure (PICA-I). In addition, the tank is fitted with a relief valve to cope with emergencies. Liquid is fed to the tank from tank trucks. A pump (P-I) supplies the flammable liquid to the process (CCPS, 2000). LPG is a highly flammable gas, whereas the release of LPG may lead to fire and explosion in the presence of an ignition source. To demonstrate the proposed approaches, this was earlier reported by CCPS (2000).

Large LPG leakage	Immediate ignition	Wind to populated area	Delayed ignition	UVCE or Flesh Fire	Ignited jet points at LPG tank	Outcomes	Frequency
A	B	C	D	E	F		

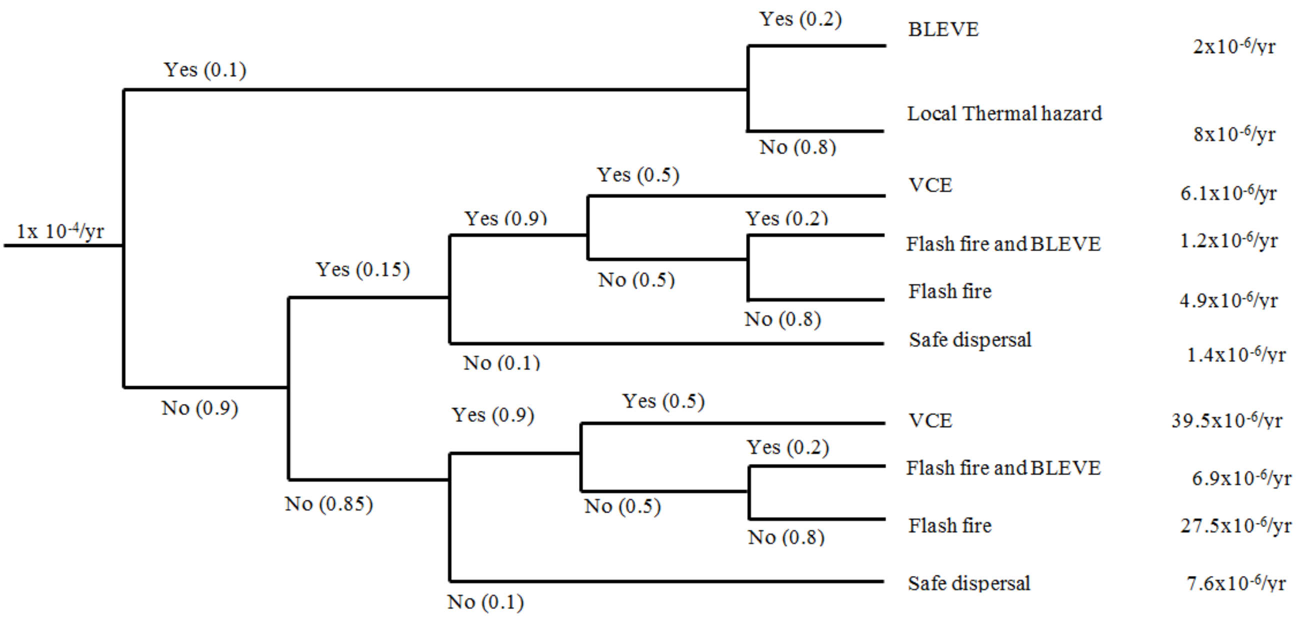


Figure.5 Event tree for analysis frequency of consequences LPG using classical method

Table.1 Frequency of consequences for large LPG leakage using fuzzy inference methods (Sequence.1)

Calculate the frequency of outcome using classical methods							
IF	Large LPG leakage	AND	Immediate ignition/YES	AND	Ignited jet point at LPG tank/ YES	THEN	BLEVE
	$1*10^{-4}$/yr		0.1		0.2		$2*10^{-6}$/yr
Calculate the frequency of outcome using fuzzy inference method							
IF	0.0001/yr	AND	0.1	AND	0.2	THEN	$3.05*10^{-6}$/yr
	$[0.5*10^{-4}$ $1.5*10^{-4}]$		0.1		0.2		$3.05*10^{-6}$/yr
	0.0001/yr		0.0518		0.2		$2.98*10^{-6}$/yr
	0.0001/yr		0.124		0.223		$3.13*10^{-6}$/yr
	0.0001/yr		0.149		0.248		$3.22*10^{-6}$/yr

The figure.5 shows the results of consequences probability using event tree analysis and the logical and arithmetic computation method for calculate the outcomes

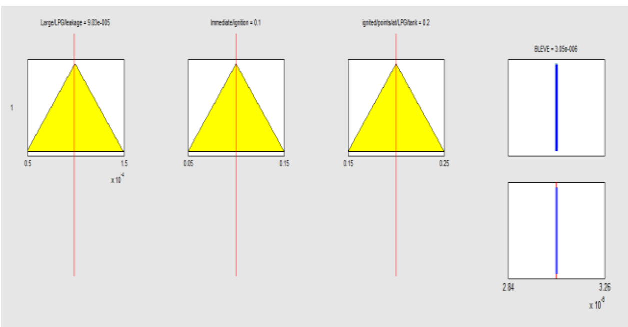


Figure.6.a Rules inferences process for BLEVE

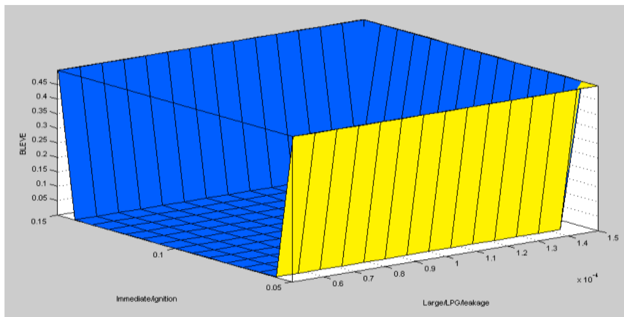


Figure.6.b Three dimensional diagram of BLEVE by large LPG leakage and immediate ignition

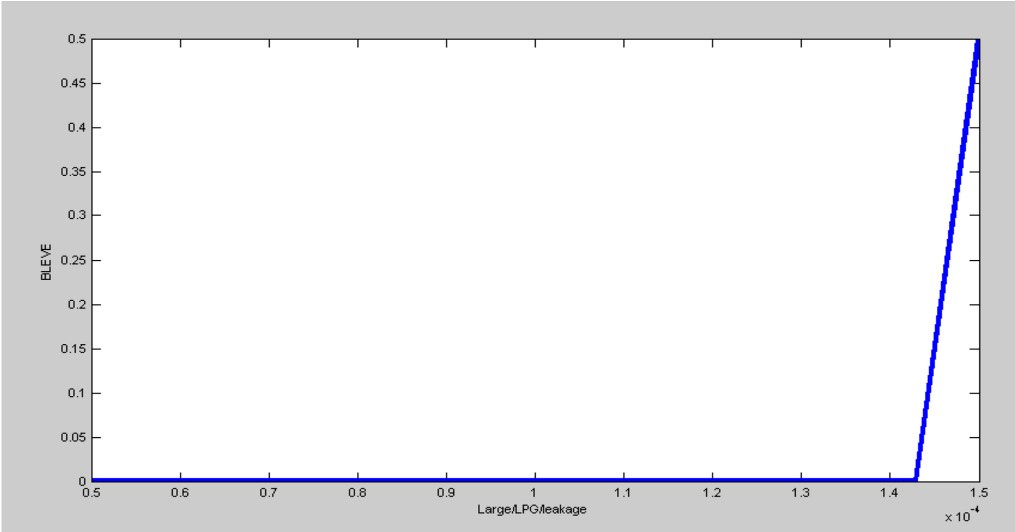


Figure.6.c Two dimensional diagram shows relationship between BLEVE and large LPG leakage

Table.2 Frequency of consequences for large LPG leakage using fuzzy inference methods (Sequence.9)

Calculate frequency of outcome using classical method													
IF	large LPG leakage	AND	Immediate ignition/ NO	AND	Wind to populated area/NO	AND	Delayed ignition/ YES	AND	UVCE or Flash Fire/ NO	AND	Ignited jet points at LPG tank/NO	THEN	Flash fire
	$1*10^{-4}$/yr		0.9		0.85		0.9		0.5		0.8		$27.5*10^{-6}$/yr
Calculate frequency of outcome using fuzzy inference method													
IF	$1*10^{-4}$/yr	AND	0.9	AND	0.85	AND	0.9	AND	0.5	AND	0.8	THEN	$13.7*10^{-5}$/yr
	$1*10^{-4}$/yr		0.85		0.8		0.85		0.45		0.75		$13*10^{-5}$/yr
	$1*10^{-4}$/yr		0.95		0.90		0.95		0.55		0.85		$14.3*10^{-5}$/yr

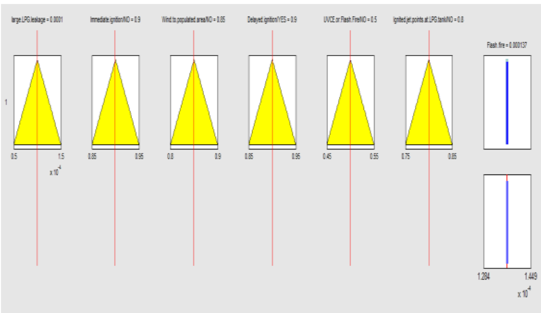


Figure.7.a Rules inferences process for flash fire

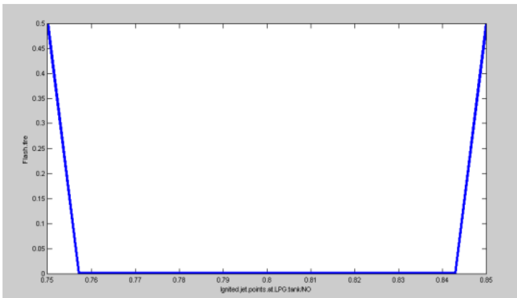


Figure.7.c Two dimensional diagram shows relationship between flash fire and Ignited jet points at LPG tank

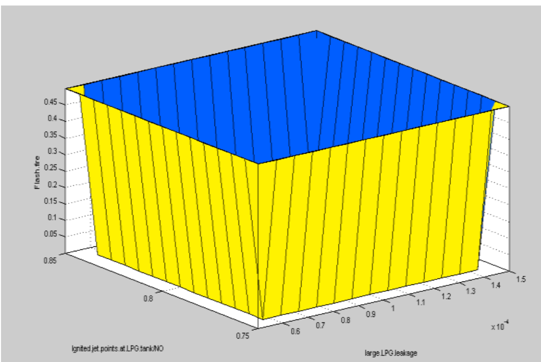


Figure.7.b Three dimensional diagram of flash fire by large LPG leakage without Ignited jet points at LPG tank

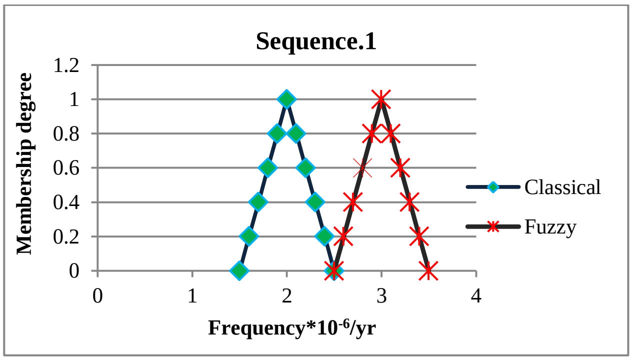


Figure.8 Comparison between arithmetic by logic and fuzzy logic methods for frequencies

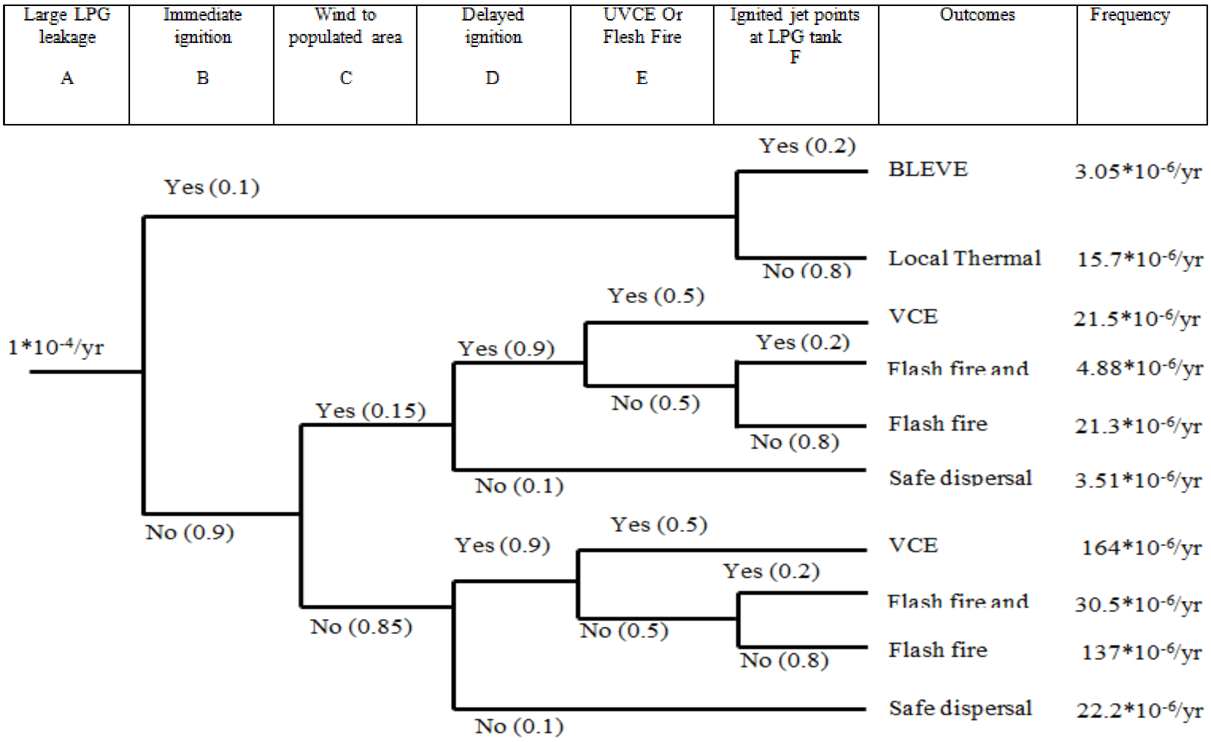


Figure.9 Event tree for the LPG leakage as initiating event with fuzzy-sugeno's results

Discussion

The study illustrates new model to calculate the frequencies of scenarios using fuzzy sets, the results demonstrate in four types of figures, the first is the rules inferences process, the second demonstrates the three dimensional diagram, the third shows two dimensional diagram, and the fourth type is comparison between two methods fuzzy and classical (logical and arithmetic computation), and the tables demonstrate the advantages of fuzzy to give different results of frequencies.
The figures has showed as rules inferences using the equation (4) and the figure.2 illustrates the process, the two and three dimensional got using the equantion.5, and the fourth type which shows the comparison of logical and arithmetic computation and fuzzy logic by alpha-cut using the equations (1), (2) and (3). Event tree analysis using fuzzy inference by Sugeno method allow us to deal with uncertainty and imprecise values of outcome's frequency, when the value of probability of outcomes comparing with the logical and arithmetic computation.

Conclusion

In this study, we proposed new model to deal with uncertainty and imprecise of outcomes of initiating events based on fuzzy event tree analysis. Event tree analysis is constructed using two different calculation approaches, the logical and arithmetic computation method (classical method) and fuzzy inference, where the fuzzy inference system using sugeno method gave results more precise than classical method and the best to deal with uncertainty. Furthermore, the results got by this model allow us to choose the best result which will be fit with system and prospecting the consequence of initiating event. Knowing that assessment of results by experts based on pessimist outcomes to get reliability in the system under study.

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