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A Study on the Application of Dynamic Risk Assessment in Chemical Process Industries

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Abstract

In conventional Quantitative Risk Analysis (QRA) process it is unable to use the accident precursor information to revise the risk profile. One of the main disadvantages is its inability to update the risk during the life of a process. Dynamic risk assessment can be used to overcome this disadvantage. Dynamic risk assessment refers to a risk management framework where frequent updates of risk evaluation information are used to evaluate the risk outcome. This uses accident precursors such as near misses and incidents to estimate likelihood of all possible end states while conventional QRA uses on static basis considering only major accidents and events. So these updated risk profiles which results from dynamic risk assessment can lead to more accurate decision making.

In this paper the dynamic risk assessment methodology is discussed in detail. First, potential accident scenarios are identified and represented in terms of an event tree, next, using the event tree and available failure data, end state probabilities are estimated. Subsequently, using the available accident precursor data, safety system failure likelihood and event tree end state probabilities are revised. Finally, the updated probabilities are used in revising the risk profile of the process system. It is more useful in chemical process industries as well as nuclear, aerospace and aviation industries where there is high likely hood of occurrence or several losses. In this research, the significance of dynamic risk assessment is demonstrated with respect to hydrocarbon storage tanks.

Keywords: Dynamic risk assessment, QRA, LNG storage terminal.

1. Introduction

Risk assessment and management is the vital part of safety in the process industries. Chemical process industries are composed of highly complex systems with variety of equipment, control systems and operating procedures. Usually chemical process industry deals with variety of hazardous materials which possess threat to human life and environment. So a small deviation from normal operation can lead to catastrophic accidents. In order to prevent such unwanted incidents, the industries adopt various safety assessment practices. Risk assessment is one of the safety assessment practices that is widely used in chemical process industries. (AIChE, 200) Risk assessment includes identification, analysis, and evaluation of risk. It is the determination of risk associated with a recognized hazard which includes determination of events that produce an accident, probability of those events and the consequence involved. Risk assessment looks in to key aspects of unwanted events such as development of accident prediction techniques, development of various accident modeling to analyse the consequence in order to reduce and thereby preventing the occurrences of the accident in future. (CCPS, 2008)

There are mainly two types of risk assessment methods, qualitative and quantitative risk assessment methods. Qualitative method is a descriptive one which gives cause and consequence as output. Hazard and operability study (HAZOP) and Failure mode effect analysis (FMEA) are most widely used qualitative methods. Quantitative risk assessment includes quantification of risk associated with hazard. It mainly includes calculation of the magnitude of potential loss and occurrence probability of unwanted event. In risk assessment practices, quantitative risk assessment method is more helpful because it provides a numerical value with which we can compare the risk possessed by various incidents. So we can categorize the risk according to its consequence level. (A. S. George, 2022) Quantitative risk assessment comprises three main steps which are hazard identification, probability assessment and consequence assessment. Hazard identification is the process of detection of events or a series of event that could lead to an expected incident. All possible scenarios which may lead to an accident are considered. It can be done using checklist, safety surveys etc. Risk estimation mainly includes probability assessment and consequence assessment. Fault tree analyses (FTA), event tree analysis (ETA), layer of protection analysis (LOPA) are generally used for risk estimation of an incident. FTA and ETA are adapted for this work. ETA is foreword modeling technique which links the initial unwanted events to all its consequences. ETA begins with initiating unwanted event and develops the possible sequences of events that lead to potential accidents. (CCPS, 2008) (A. S. George, 2017) The end states depend upon success and failure of the safety systems associated with it. Event tree provide a systematic way to record the accident sequences and defining the relationship between the initiating events and subsequence events that results in accidents. This method provides how incidents occur with its failure of probability. Numerical failure probabilities are assigned to safety systems and using those values the probability of occurrence events can be simply calculated.

In consequence assessment potential consequences are represented in numerical values. Consequence assessment has different approach depending upon its specific application. It can be in the form of loss to the company or risk values. Consequence matrices can be used for this kind of evaluation which converts different types of consequences to loss to company. The final step is risk calculation. It can be simply done by multiplying probability of occurrence of unwanted event by the related consequence. The risk estimated should be lower than the standard risk limit. If it is not in acceptable region engineers should give attention to reduce the risk by introducing various safety systems and/or changing the design parameters.

Quantitative risk assessment method is the well-established risk assessment method which is commonly used by the safety engineers in chemical process industries. As we have all the safety systems and man power in order to eliminate the risk possessed in the industry still we hear news of catastrophic accidents in chemical process industry. The accident at BP’s Texas City refinery can be taken as example of failure of conventional QRA approach. Explosions and fires on March 23, 2005 at BP's Texas City refinery that killed 15 people and injured 180 and another incident on 10 August 2008 in which heavy explosions occurred in Sunrise propane storage facility in Toronto, Ontario killing two and causing evacuation of thousands of people are examples of such tragic incidents. This may be partly attributed to a major disadvantage of the conventional QRA approach which is its inability to capture variations in the risk profile as the process is subjected to upsets, deviations from normal operation, aging of assets, and human intervention. Also, risk control strategies in QRA are developed based on major events. Frequencies of such events are very low and thus not much information or scientific data are available to yield accurate results in risk analysis. Chemical process industries are complicated and dynamic in nature. So it involves various time dependent factors. (Khan, 2009) Our current risk assessment methods are not capable of dealing with those time dependent characteristics like aging of equipment and component, hardware failures, change in season, process changes and disturbances. So risk possessed by the industry changes over time. Failure probability of the safety systems also changes over time. So it can be stated that available accident modeling techniques has its own limitations. It has inability to update the risk during operation of the plant. So new methods should be adopted to update the operational risk in order achieve more accurate risk assessment. (N. KKhakzad, 2012) Dynamic risk assessment can use historical data to update the failure probability of the safety systems. So industry can get updated consequence probability. The objective of the project is to use of Bayesian theorem in dynamic risk assessment of LNG storage terminal. The real time data is used here for case study.

2. Methodology: Dynamic Risk Assessment

Conventional risk assessment methods are static in nature. The oil/gas, chemical, petrochemical and other process industries are dynamic in nature. The process condition is dependent on variation of certain process variables which is affected by several time-dependent effects such as season changes, ageing of equipment/components, sequential dependencies, operator experiences and operation time, inspection and testing time interval etc. But, the conventional risk assessment methodologies have limited ability to quantify these time dependent effects.

Depending on the rate of event occurrence in a system the current risk profile could be significantly different from the original risk of the process calculated at the design stage. This shows that the design stage data may not be very reliable after the process is subjected to deterioration, fatigue and possibly human intervention. Risk has two major parameters which are failure probability and consequence. Failure probability in this methodology is continuously updated and changes every time an accident sequence precursor (ASP) such as incidents and near misses occur in the system. The resulting risk profile developed after the failure probability update is referred to as the posterior risk. At the design stage of the process the original failure probability function, herein denoted as the prior function, is determined in terms of a probability distribution due to the uncertainties involved. (Qingqing, 2023) With the ASP data available, Bayesian theory is used to determine the posterior failure probability in the form of a probability distribution. Subsequently, the posterior risk profile is obtained simply by multiplying the new failure probability function by its related consequence. (Rathnayaka, 2012)

2.1 System Definition

The first step in dynamic risk assessment method is defining the system boundaries. The system is composed of many subsystems such as people, software, procedures, equipment, hardware and environment. The failure in these complex and nonlinear systems can result major accidents. So it is important to understand relationship between each system. The boundaries of the systems should be clearly mentioned so that each incident can be classified accordingly. Understanding of the systems, subsystems, system interfaces and their interactions is critical to identifying the hazards, accident process and safety barriers required.

2.2 Hazard Identification and Analysis

Once the system and its boundaries are defined the next step is hazard identification and its analysis. Real time abnormal data are collected and analyze how these deviations can lead to an accident. This step identifies the most likely scenarios, types of failures and end-states associated with an incident. After determining the scenario, the initiating abnormal event and all safety systems serving as protective layers to reduce or eliminate the effect of that event are identified. This information is then used to form the event tree. (Yun G., 2009) This event tree will show the relations between failure or success of each safety system with the possible end-states. The result of the analysis gives out five severity levels, which are known as: safe, near miss, mishap, incident and accident. An incident notification report can be used for hazard identification and analysis. (CCPS, 2008) The industry should keep a record of abnormal events. Identification of safety barriers to prevent or reduce the effect of the accident is an important step in hazard analysis. The failure of all safety barriers will lead to the accident. Four safety barriers are identified as the result of analysis. These are typical layer of protection usually used in process industries.

2.3 Accident Process Modelling

The accident model used here was developed by kujath et al. (2010) for oil and gas process environment. Here four safety elements were considered and placed in sequential order. The sequential cause consequence relationship is presented with the help of event tree and fault tree analysis. The safety barrier failure probability is analyzed by the use of fault tree analysis. The top event denotes the failure of the safety barrier. The secondary layer is associated with sub safety barriers. A description of safety barriers is given below.

Release Prevention Barrier (RPB)

As the name indicates it describes the release of material or energy to the environment. In most of the cases an accident is initiated with such kind of release. Fault tree is constructed by taking the top event as the failure of release prevention barrier. The main sub safety elements that cause RPB failure are: (1) operational error prevention barrier failure (Failures occur when the system is in an operating condition. Manual operational errors are often recognized as the main cause for this sub-safety element failure), (2) physical/technical prevention barrier failure (3) maintenance prevention barrier failure (Poor maintenance, release during maintenance, and erroneous maintenance are some of causes for the failure this sub-safety element) and (4) process upsets prevention barrier failure.

Dispersion prevention barrier (DPB)

When the release prevention barrier fails the next barrier is dispersion prevention barrier. It prevents or limits the spreading of the material released. Passive and active barriers are used for dispersion control. Fault tree constructed by taking top event as dispersion prevention barrier. The fault tree for this safety barrier identified passive barriers such as bunds, retention walls, dikes and drainage and active barriers such as inserting, ventilation and detection systems as sub-safety elements. (Ravi K. S., 2016) Safety elements such as manual and automatic isolation and emergency shutdown systems are also applied to limit the dispersion of hazardous material.

Ignition prevention barrier (IPB)

This barrier is used to control or mitigate the ignition of flammable material. If dispersion prevention barrier fails, the toxic or flammable material disperse in environment and it may ignite causing a fire and explosion. Therefore, all ignition sources should be identified and possible safety function should be provided. In industries there are a numbers of ignition sources like flames, hot works, hot surfaces, hot gases, friction and electricity. The barriers failure probability is identified with the help of the fault tree. Permanent passive barriers and controllers are used as ignition barrier.

Escalation prevention barrier (EPB)

Once an accident occurs like fire or explosion it may propagate in to nearby equipment or building triggering one or more secondary events. This process is known as “domino effect”. It is a chain reaction. Secondary events occur after primary events as heat radiation, projectiles and over pressure. The effect of these events are higher. Therefore, relevant passive barriers like fire wall, blast wall etc. and active barriers should be installed to isolate the surroundings to prevent domino effect.

2.4 Updating Mechanism Using Bayesian Theory

Event tree analysis and fault tree analysis are used to compute the failure probability of safety barriers described above and the occurrence probability of consequences. Quantitative risk assessment method also follows the same method. The basic event probabilities are taken from the literature, reliability data base and from the expert opinion. (M Abimbola, 2014) These data include uncertainties. These failure probability and consequence probability remains same as plant operates over time, but actual probability may change due to operation of the plant. So these failure and occurrence probability has to be updated according to time. Bayesian updating mechanism is used to update those values. It can reduce the uncertainty and prove more accurate value each time. The steps in Bayesian updating mechanism are given below

Prior Probability Calculation

The prior probabilities of safety barriers are calculated using event tree and fault tree model. These include design stage data. The basic failure probabilities are taken from literature review or OREDA database. This initial probability is updated with use Bayesian theory when real-time plant data arrives. Reliability data are usually provided as component failure modes and rates and used as the input of risk assessment models, such as fault tree/ event tree analysis. Prior probability for this work is also calculated using the fault tree and event tree analysis.

Estimation of Likelihood Failure Probability

Likelihood probability is estimated using the plant real time data. The plant should keep a record of abnormal events happened. It is called incident notification report. This data is used to estimate likelihood probability of events. The abnormal events are categorized in to accident, incident, mishap and near miss according to the information from the plant safety experts and using IS 3786 and safety matrix. In this work nine years’ data are collected. The likelihood probability is estimated using real plant abnormal event data as follows (Rathnayaka, S., et al., (2011):

- Find the number of abnormal events is each year.
- Using these numbers estimate the number of potential success and failure states for each safety barrier.
- NS,i = N C,k, for k = i
- NF,i= Σ NC,k, for k > i; i = 1, 2, 3, 4 and k = 1, 2, 3,4,5

Where Ns,i and Nf,i are number of success and failures respectively for the for i'th barrier.

After the calculation of number of success and failure of each barrier is done Likelihood probability is estimated using:

P (data/ xi) = NF,i / (NF,i + NS,i)

Here we get the likelihood probability data for each safety barrier for each year.

Posterior Failure Probability

Substituting prior and likelihood probability in the baye's equation we get the updated failure probability of the safety barrier. The updated failure probability or posterior failure probability can be used to estimate the updated occurrence probability by propagating these value through the branches of event tree.

$$p\left(\frac{xi}{data}\right) = \frac{p\left(\frac{data}{xi}\right)p(xi)}{\sum p\left(\frac{data}{xi}\right)p(xi)}$$

The failure probability of safety barrier xi, is assumed to be identical and independent. In the above equation p(xi) is the prior failure probability of the safety barrier and p(data/xi) is likelihood probability of safety barrier which is estimated from the plant real time abnormal data. The denominator denotes the normalizing factor. (D. Zhu, 2007)

Bayesian network is relatively new technique in the field of process safety and risk analysis. Application of Bayesian network in risk analysis is very advantageous as it can combine the expert judgment and quantitative knowledge to estimate risk. Also, Bayesian network demonstrates changes of variables with time through reasoning process. This dynamic risk methodology has the ability to provide updated probability with time, to incorporate inspection and testing time interval, which shows its effect on the critical event probability.

3. Dynamic Risk Assessment of LNG Storage Terminal

3.1 System Definition

The main process on this terminal is conversion of LNG to natural gas at atmospheric temperature. LNG is unloaded from tankers to LNG storage facilities. Marine terminal pumps transfer LNG from storage to warming systems, where the liquid rapidly returns to vaporized state. Ambient temperature system use heat from surrounding air to vaporize the cryogenic liquid. Block diagram of the plant is provided.

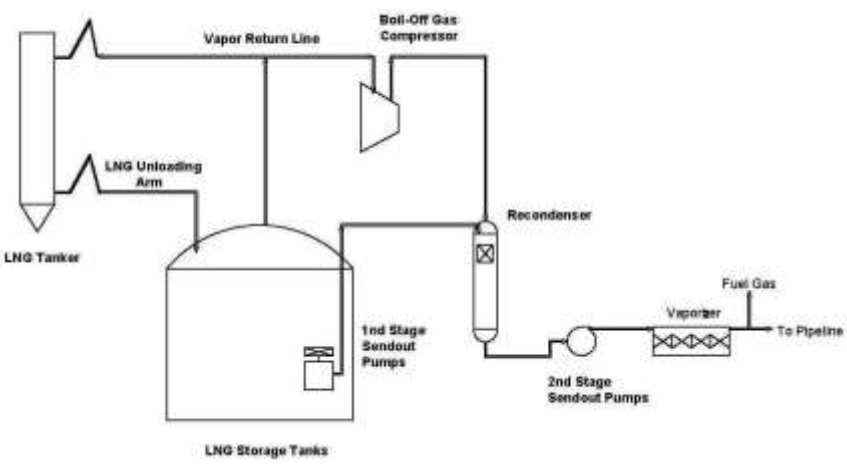

Fig. 3.1 LNG Plant Layout

A typical LNG storage facility has following systems (1) LNG Unloading- Jetty, (2) LNG storage system, (3) Boil Off gas (BOG) system, (4) LNG sent out system, (5) Flare system, (6) Nitrogen system, (7) power generation system. The data from the following systems are considered for dynamic risk assessment of LNG terminal. In order to consider all system a crystal clear working knowledge of the plant is essential. The study is done as the testing of the application of dynamic risk assessment in LNG storage terminal.

3.2 Hazard Identification and Analysis

The next step is identifying and classifying all potential undesirable events according to its severity and understanding its relationship with the safety systems. In this study all undesired events are identified and analyzed with use of incident notification report of nine years gathered from LNG storage terminal. After identifying the abnormal events they undergo event sequence analysis and safety function applicable to prevent the initiation or mitigation or termination of the accident process is determined. The result of the analysis gives out five severity levels, which are known as: safe, near miss, mishap, incident and accident. The accident sequence model adopted in this work is from kujath et al. (2010).

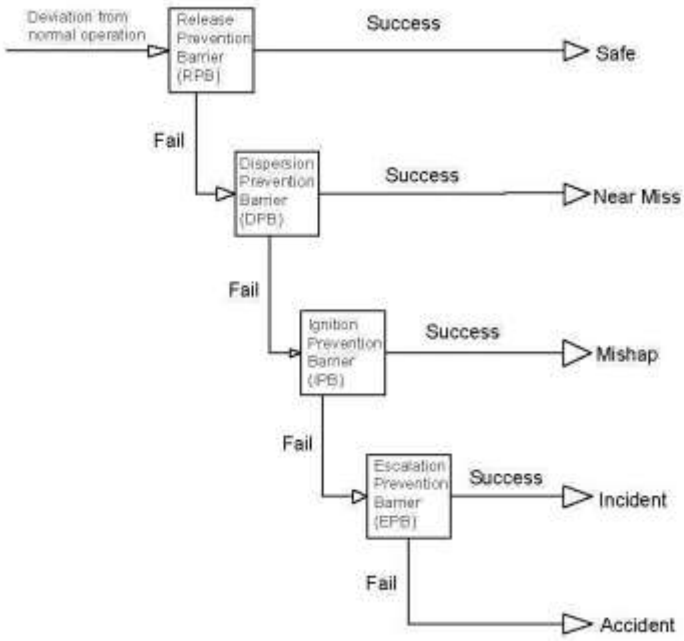

Fig. 3.2 Event sequence diagram for LNG storage terminal

The incident notification report collected are analyzed and assigned severities to each incident. Safety expert's opinion from the LNG plant is also used for this analysis. They have better idea how an undesired event will result to an accident. The analysis gives out an event tree by sequential arrangement of the safety barriers. The definition of each barrier is already given in the previous chapter. Four safety barriers were identified. The failure of all four will lead to an accident.

3.3 Accident Process Modeling

The above mentioned accident model with the event tree describes how an accident occurs in the industry. The failure barrier is independent and mutually exclusive. The failure probability of these four safety barriers are determined by constructing a fault tree taking failure of each safety barrier as the top event. The fault tree for each safety barrier is constructed. The failure probabilities of basic events are taken from the literatures (Khan et al., 2002, Rathnayaka, S., et al., 2011). The accident model used for dynamic risk assessment was taken from the literature (Rathnayaka, S., et al., 2011). These failure probabilities constitute the prior failure probability which is used in the Bayes theory in order to estimate the updated probability. In conventional risk assessment method these values remain unchanged, but in dynamic risk assessment these failure probabilities get updated as the new data are added. Plant real time data is used for that. So the uncertainty along with the probability get reduced. The failure probability of each safety barrier is given below:

Table 3.1 Prior failure probability of safety barrier (Rathnayaka, S., et al., 2011)

Safety barrier	**Failure probability P(xi)**
Release Prevention Barrier (RPB)	0.0527
Dispersion Prevention Barrier (DPB)	0.0616
Ignition Prevention Barrier (IPB)	0.1060
Escalation Prevention Barrier (EPB)	0.0271

The failure probability of the safety barrier is used in the event tree to find out the occurrence probability of the end states of event tree simply by multiplying the probabilities of the associated branches leading to a specific end states. It is the same method which we use in normal event tree analysis to find the end state probability.

Table 3.2 Prior consequence occurrence probability (Rathnayaka, S., et al., 2011)

Consequence	Occurrence Probability
Safe	9.4×10^{-1}
Near miss	4.9×10^{-2}
Mishap	2.9×10^{-3}
Incident	3.3×10^{-4}
Accident	9.3×10^{-6}

3.4 Updating Mechanism Using Bayes Theorem

The failure and occurrence probabilities computed by fault tree and event tree include some amount of uncertainties. In fault tree construction the basic event tree probabilities used are point values which are taken from reliability data base and literature. This values are taken for all similar industries. Real time plant data are not used in conventional risk assessment method. (Woodward, 2010) Dynamic risk assessment method uses bayes theorem to update these risk profile with use of the data gathering from the plant. As the new data comes the failure probability of safety barriers tree and event tree analysis.

Estimation of likelihood failure probability

Plant real time data is used to estimate the likelihood failure probability. This is an important step in the dynamic risk assessment. The table 3.3 list the cumulative abnormal data from the LNG storage terminal. They have nine years' data. The steps to estimate the likelihood probability is explained in the previous chapter.

Table 3.3 Cumulative number of abnormal events for 9 years

Year	Safe	Near miss	Mishap	Incident	Accident
2004	1	2	2	2	0
2005	2	5	5	3	0
2006	5	13	9	5	0
2007	9	21	13	6	0
2008	12	37	17	8	0
2009	15	46	20	9	0
2010	22	65	24	12	1
2011	28	89	27	13	1
2012	31	94	28	14	1

Likelihood probability is estimated using cumulative umber of abnormal events with the following equation:

$$P\left(\frac{data}{xi}\right) = \frac{Nf,i}{Nf,i + Ns,i}$$

Where P (data/ xi) is the likelihood probability and Ns,i and Nf,i are number of success and failures respectively for the for i'th barrier. Hence the likelihood probability for each safety barrier is given in table 3.4

Table 3.4 Likelihood probability for each barrier

Year	RPB	DPB	IPB	EPB
2004	0.857	0.667	0.500	0.000
2005	0.866	0.615	0.375	0.000
2006	0.843	0.518	0.357	0.000
2007	0.816	0.475	0.315	0.000
2008	0.837	0.403	0.320	0.000
2009	0.833	0.386	0.310	0.000
2010	0.822	0.362	0.351	0.076
2011	0.822	0.315	0.341	0.071
2012	0.815	0.313	0.348	0.067

Posterior estimation of failure probability

Posterior failure probability or updated failure probability is estimated using bayes theorem. Prior failure probability and likelihood failure probability are used for the estimation of updated failure probability.

$$p\left(\frac{xi}{data}\right) = \frac{p\left(\frac{data}{xi}\right)p(xi)}{\sum p\left(\frac{data}{xi}\right)p(xi)}$$

The steps to estimate the updated probability is explained in the previous chapter. Table 3.5 lists the updated failure probability for nine years and fig 3.3 illustrates their distribution with time. The graphical representation gives a view of how the failure probability changes over time as the new data is added.

Table 3.5 Posterior failure probability data for each barrier

Year	RPB	DPB	IPB	EPB
2004	0.1141	0.1645	0.1554	0.0000
2005	0.1153	0.1517	0.1166	0.0000
2006	0.1122	0.1278	0.1110	0.0000
2007	0.1086	0.1172	0.0979	0.0000
2008	0.1114	0.0994	0.0995	0.0000
2009	0.1109	0.0952	0.0964	0.0000
2010	0.1094	0.0893	0.1091	0.0355
2011	0.1094	0.0777	0.1060	0.0332
2012	0.1085	0.0772	0.1082	0.0312

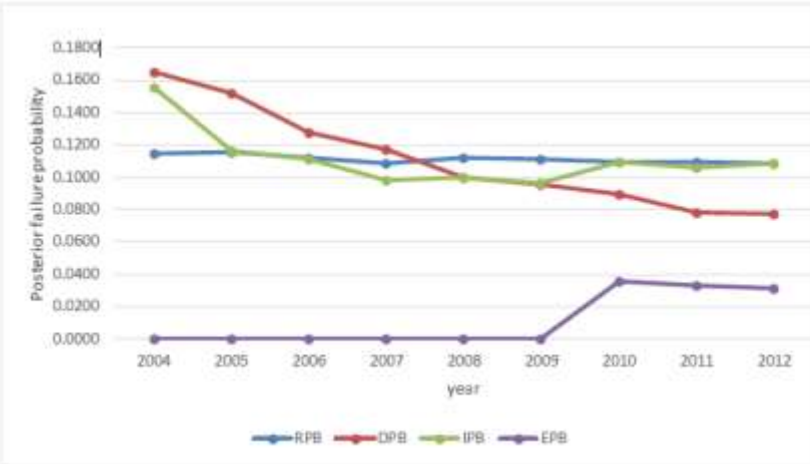

Fig 3.3 Posterior failure probability distribution of safety barrier for nine year

Estimation of updated consequence occurrence probability

With the updating of the failure probabilities of the safety barriers, occurrence probability of each consequence is also updated. It shows that as the new data are arrived the probability changes. The updated failure probability is used in the corresponding branches of the event tree. The failure probability is propagated through the branches of the event tree as we do in normal event tree analysis. The results are listed in table 3.6

Table 3.6 Posterior occurrence of each abnormal event over 9 years

Posterior occurrence of each abnormal event over 9 year					
Year	Safe	Near miss	Mishap	Incident	Accident
2004	0.88590	0.09533	0.01585	0.00292	0
2005	0.88470	0.09781	0.01545	0.00204	0
2006	0.88776	0.09789	0.01275	0.00159	0
2007	0.89136	0.09591	0.01148	0.00125	0
2008	0.88856	0.10036	0.00998	0.00110	0
2009	0.88910	0.10034	0.00954	0.00102	0
2010	0.89056	0.09967	0.00871	0.00103	2.99487×10^{-5}

2011	0.89056	0.10094	0.00760	0.00087	2.99487×10^{-5}
2012	0.89149	0.10013	0.00747	0.00088	2.82872×10^{-5}

4. Results and Discussions

This study has demonstrated the importance of the dynamic risk assessment approach in the process industries. After an overview of the concepts of QRA this work begins by a detailed description of the dynamic risk assessment approach using accident precursor data and Bayesian theory. This study shows that the dynamic risk assessment approach is a powerful tool with updating and predicting abilities which can be applied successfully to the process industry. The methodology may be used as part of a QRA approach to develop the real time risk profile of a process based on the number and type of deviations, incidents, or near misses. This emphasizes more on the importance of a strong safety culture throughout the process facility to monitor and record all abnormal events experience by the process including process upsets, near misses and incidents. With a strong safety culture in place, the application of this tool assures the availability of the real time risk profile of the process. Using the real time risk profile along would help in rectifying issues early on before they escalate to accident.

The figure 3.3 illustrates the distribution of updated failure probabilities of safety barriers. It gives a clear vision of change of the probability with respect to time as the new data are added. The dynamic aspect of process plant is equipment/components ageing phenomenon. The failure rate values are considered constant with time, but in practical life, due to ageing the failure rate tends to increase with time. The failure probability of safety barrier is reduced with respect to time. In dynamic risk assessment the result of the risk assessment depends upon the real time data used. So in order to get more accurate risk assessment it needs a complete incident notification report. But in India most the companies do not keep the data. The record major events only. This decrease the accuracy of this kind risk assessment. But it is clear that dynamic risk assessment can provide a better risk profile by including the real time data in to account. Four safety barriers namely release prevention barrier, dispersion prevention barrier, ignition prevention barrier and escalation prevention barrier are used in this work to describe an accident. The testing of dynamic risk assessment model in LNG storage terminal was done. A quantitative assessment was done to validate the dynamic model. The failure probability of each safety barrier is estimated using fault tree analysis. The occurrence probability of each consequence was estimated using the event tree analysis. These are known prior estimates. In conventional quantitative risk assessment model this remain unchanged throughout the operation of the plant. From the plant data it’s clear that events such as safe, near miss are more frequent but have lesser severity level.

5. Summary and Conclusion

Dynamic risk assessment method is an extension of conventional quantitative risk assessment. In conventional QRA, risk is estimated in static basis. The failure probabilities of various safety systems and consequence probabilities are estimated from expert opinion or database or literature. In QRA this remains unchanged throughout the operation of the plant. But as the plant operates over time, the level of risk changes. Dynamic risk assessment method can overcome these disadvantages by applying suitable updating techniques for the failure probabilities. It can also be used to predict the probability of abnormal events utilizing accident precursor data, helping to achieve inherently safer operation. DRA can model chemical process industry accidents caused by process hazards and human and organizational factors effectively with systematic procedures and quantitative outputs. It can utilize precursor data to overcome the uncertainty associated with reliability data and to quantitatively estimate the dynamic risk that supports dynamic decision making.

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