Development of Rule-Based Advisory System from Modified Hazard and Operability Study on Fatty Acid Fractionation Column

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Abstract

A modified Hazard and Operability Study (HAZOP) algorithm has been proposed in order to develop process deviation relationships between two study nodes in HAZOP study. In order to apply the modified HAZOP study, a rule-based advisory system, which consists of knowledge-based and inference engine has been developed. The main objective of building the rule-based advisory system is to facilitate the decision-making process and also to conduct the database management efficiently. Microsoft Access™ and Visual Basic™ have been used to develop the knowledge-based and the inference engine respectively. The base case in this study is a fatty acid fractionation column of an oleo chemical plant. As a result of the modified HAZOP study application, a new documentation system of HAZOP study is produced in the advisory system developed. In comparing with the conventional HAZOP study, the main improvement made by the modified HAZOP study is that it contains the main and side causes/consequences database category, which are related to the analyzed guideword and the identified process deviation relationship.

Keywords:

Hazard Identification, HAZOP, Advisory System, Expert System, Rule-based System

Introduction

In the assessment of risks, and the planning of measures to reduce or control risks, hazard identification is an important element. Among the methods used to identify hazards are Preliminary Hazard Analysis (PHA), Concept Hazard Analysis (CHA), Checklist and Hazard and Operability Study (HAZOP). However, HAZOP is the most widely applied method for the identification of hazards in the process industry [1, 2]

HAZOP is defined as a systematic approach to identify potential hazards and operational problems [3]. HAZOP has proven to be one of the most powerful and useful analytical tools and rapidly becoming a standard technique.

However, the existing safety procedure of HAZOP carries some problems and deficiencies, as it does not cover all types of hazards and risk factors. The major problem with HAZOP relates to the level of detail in the study, especially to carry out hazard analysis in a complex process and to develop the linkage propagation of the fault or hazard identified to each of unit plant.

Besides, nowadays, new demands are constantly challenging the process chemical industry and one of the main challenging demands in safety analysis is to handle the accumulated amount of data and knowledge in such a way that it is available at the right place and time. Hence, there is a need in plant safety to transfer the experts' knowledge into an intelligent system of computer-aided program particularly for reducing the time, effort and costs involved in the safety analysis domain [1].

Problem Background

In the current algorithm of the HAZOP study, relationships of process deviations information between two or more streams have not been considered in detail. The lack of linkages of the information between study nodes identified may lead to an incomplete database analysis of the study. Hence, a modified algorithm should be developed to link of and also for exchange of information between study nodes in order to set up a comprehensive HAZOP study database.

With the modified HAZOP algorithm, an advisory system is needed in which the expert system approach will be used as a basis for developing the structure. The advisory system is expected to demonstrate how the modified algorithm could manage the knowledge used in the study, as to make it available at the right place, where it is needed. In this research, the causes and consequences of a process deviation will be used in other mode of process deviations (i.e guidewords). The expert system is used to handle facts, rules and showing the desired output (causes and consequences of process deviations) that are related to the input data (guidewords) specified.

Approach and Methods

The following discussion is divided into two main sections. Firstly, the modified algorithm proposed will be discussed in general and then followed by the detail discussion on the main framework of the advisory system. The base case for the study is a fatty acid fractionation column of an oleo-chemical plant.

The Modified HAZOP Algorithm

The modified algorithm for the HAZOP study proposed connects information between two of study nodes.

Generally, the algorithm consists of three main phases. The first phase involves the conventional HAZOP study procedure. The objective of this phase is to identify all possible causes and consequences for every process deviation specified.

In the second phase, the objective is to create a process deviation relationship between the two study nodes, and it involves two procedures. First, is to select another study node to be analyzed together with the previous study node. Second, is to analyze both study nodes in order to obtain a relationship between them.

Finally, in the last phase, the objective is to connect all the causes or consequences of study node B to be put together as causes or consequences for study node A based on the process deviation relationship identified. This information will be classified as 'Side Causes' or 'Side Consequences'. If everything completes, the procedure returns to the first phase.

Development of Advisory System

The expert system approach is used as a basic structure for the development of the advisory system in this research. The expert system approach is used to conduct decision- making process and also to organize knowledge systematically to be available at the right place, where it is required. The two components used in the development of advisory system are the knowledge-based and the inference engine.

Development of Knowledge-Based

The development of knowledge based is carried out for storing all the causes and consequences of process deviation that are obtained from the conventional HAZOP study. Firstly, the conventional HAZOP study is carried out. The process is divided into 4 study nodes, which are Study Node 1(Feed Stream), Study Node 2 (Bottom Stream), Study Node 3 (Vent Stream) and Study Node 4 (Distillate Stream). When the study is completed, all the information (causes and consequences) is stored in a database system using Microsoft Access^{TM}. Examples of causes and consequences from a process deviation for one study node have been shown in Figure 1 and Figure 2 respectively.

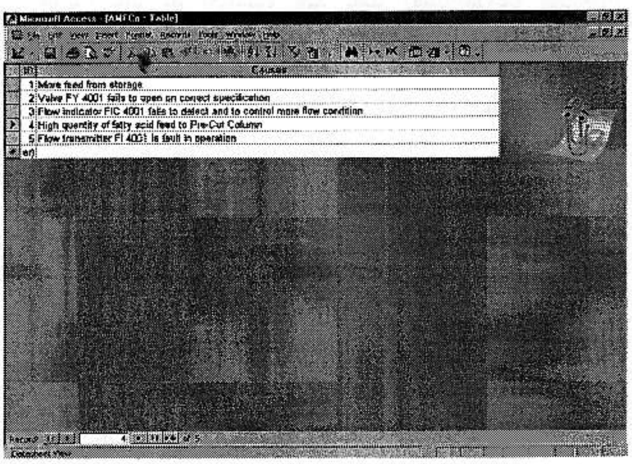

Figure 1 - Causes of More Flow for Study Node 1

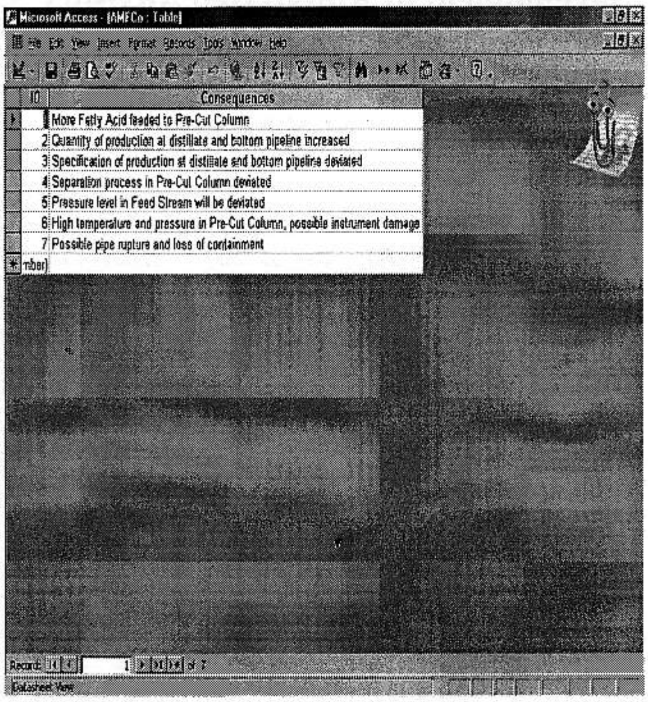

Figure 2 - Consequences of More Flow for Study Node 1

Development of Rule-Based

The production of rule-based method is used to represent the behavior of process deviation relationships between two study nodes specified. The 'process deviation relationships' is a term to show how one process deviation from one study node could affect or could be affected by other study nodes, as an example, 'if feed is more flow then output is more flow'. The plant simulation data is used as the information source in order to predict the process deviation relationships. There are two types of rules that have been developed:

(i) Rule I: to identify a kind of process deviation relationship according to the guidewords specified.

(ii) Rule II: to connect the process deviation relationship with the causes and consequences of HAZOP study that related.

Two categories of rules will be produced in Rule I, which are True Rules Category and False Rules Category. The 'True Rules Category' provides rules, which identify the type of process relationship that relates to the specified study nodes. If the specified condition of study node A produces changes in study node B, then a process deviation relationship is obtained. As an example, this relationship will be structured as:

"IF Stream A is More Flow, THEN, Stream B is More Flow"

Meanwhile, the 'False Rules Category' contains rules that will never identify such relationships, as shown below:

"IF Stream A is More Pressure, THEN, Stream B No Deviation"

Table 1 shows the rules developed for feed stream.

Table 1 - The Rule-Based for Feed Stream

Category	Production Rule-Based
True Rules	IF Feed Stream = More Flow, THEN Bottom Stream = More Flow, Vent Stream = More Flow AND Distillate Stream = More Flow
	IF Feed Stream = Less Flow, THEN Bottom Stream = Less Flow, Vent Stream = Less Flow AND Distillate Stream = Less Flow
	IF Feed Stream = More Temperature, THEN Bottom Stream = More Flow, Vent Stream = Less Flow AND Distillate Stream = More Flow
	IF Feed Stream = Less Temperature, THEN Bottom Stream = Less Flow , Vent Stream = More Flow AND Distillate Stream = Less Flow
False Rules	IF Feed Stream = More Pressure, THEN Bottom Stream = No Deviation, Vent Stream = No Deviation AND Distillate Stream = No Deviation
	IF Feed Stream = More Pressure, THEN Bottom Stream = No Deviation, Vent Stream = No Deviation AND Distillate Stream = No Deviation

The next procedure is to develop Rule II, which refers to the results found in Rule I. Rule II has also been categorized into 'True Rules Category' and 'False Rules Category' as Rule I. The structure of the True Rules Category is based on the following example:

" IF Feed Stream = Less Flow AND Vent Stream = Less Flow AND Bottom Stream = Less Flow AND Distillate Stream = Less Flow, THEN Less Flow Causes and Consequences of Feed Stream = Main, AND Less Flow Consequences of Vent Stream = Side, AND Less Flow Consequences of Bottom Stream = Side".

Meanwhile, an example of False Rules Category is shown as below:

"IF Feed Stream = Less Pressure AND Vent Stream = No Deviation AND Bottom Stream = No Deviation AND Distillate Stream = No Deviation THEN Less Pressure Causes and Consequences of Feed Stream = Main".

The statement of 'Main Causes and Main Consequences' is a term to show that the facts are obtained directly from the result of study node being analyzed. On the other hand, the statement of 'Side Causes and Side Consequences' is a term to show that the facts are obtained from other sources of study node being analyzed.

Development of Inference Engine

The development of the inference engine is very essential as it applies rules that integrate the process deviation relationship from knowledge acquisition process with the causes and consequences of HAZOP study contained in knowledge-based as the final result.

The analysis of the advisory system starts with the identification of process deviation relationship and ends up with searching for causes and consequences of HAZOP study that are related to it.

The rules that were developed from the knowledge acquisition process will be directly stored in the source code programming in order to get the result. The rules are structured using the 'Select Case Statement' and also 'If...Then Statement' functions. Select case statement is used to execute one of several groups of statement, depending on the value of an expression. Meanwhile, the 'If...Then Statement' is used when a comparison has to be made.

In storing Rule I, the 'case' or 'if' condition will be the guideword, meanwhile the 'statement' will be the process deviation identified, as shown in the following example:

```
Case "Feed"
  If cboGuidePri.Text = "Less Flow" Then
     picAna2.Print "Vent (Deviation Rate = Very High) =
     Bottom (Deviation Rate = High) = Distillate (Deviation
     Rate = Very Low) = Less Flow"
     picAna2.Print "Please press Enter III for HAZOP
     Database"
  ElseIf cboGuidePri.Text = "More Pressure" Then
     picAna2.Print "Vent = Bottom = Distillate = No
     Deviation"
     picAna2.Print "Please press Enter III for HAZOP
     Database"
  Else
     picAna2.Print "Fault Data Input!"
  End If
```

On the other hand, for the II, the 'case' or 'if' condition will be the process deviation identified, meanwhile the 'statement' will be the searching procedure to get the causes and consequences of HAZOP study, as shown in the following example:

```
Case "Feed"
 If Guide = "Less Flow" Then
  adodcAlfca.Visible = True
  txtAlfca.Visible = True
  adodcAlfco.Visible = True
  txtAlfco.Visible = True
  cmdNextA.Visible = True
  adodcSideDlfco.Visible = True
  txtSideDlfco.Visible = True
 ElseIf Guide = "Less Pressure" Then
  adodcAlpca.Visible = True
  txtAlpca.Visible = True
  adodcAlpco.Visible = True
  txtAlpco.Visible = True
EndIf
```

All of these rules are using ActiveX Data Object (ADO) function that exposed the Microsoft Jet database engine (used by Microsoft Access™) to Visual Basic programmer and allowed developers to assess Microsoft Access™ tables directly. Therefore, this function is used in the source code for Rule II to get the causes and consequences of HAZOP study (searching procedure).

Results

All the main outputs of the advisory system program are presented and divided into two sections; feed stream results and vent stream results.

Feed Stream Results

The following discussion is based on the feed stream analysis result. The main objective of the first phase in the advisory system procedure is to define the type of study node or stream, which required to be analyzed. Figure 3 shows the program interface developed for advisory system to start an analysis.

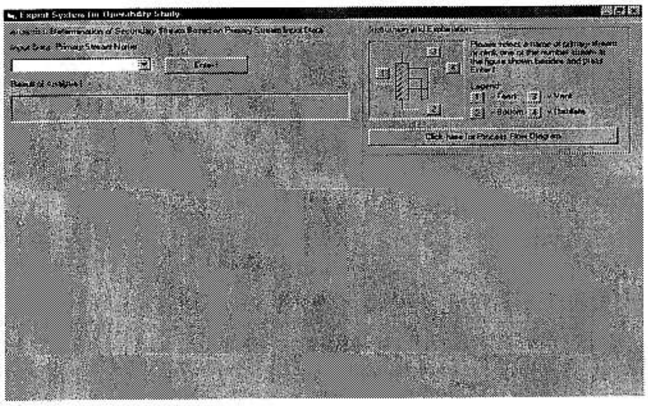

Figure 3 - Initial User Interface of Advisory System

If the feed stream has been selected for the primary stream, and the "Enter I" command button has been clicked, then the program will show 'No Secondary Stream' statement, as shown in Figure 4.

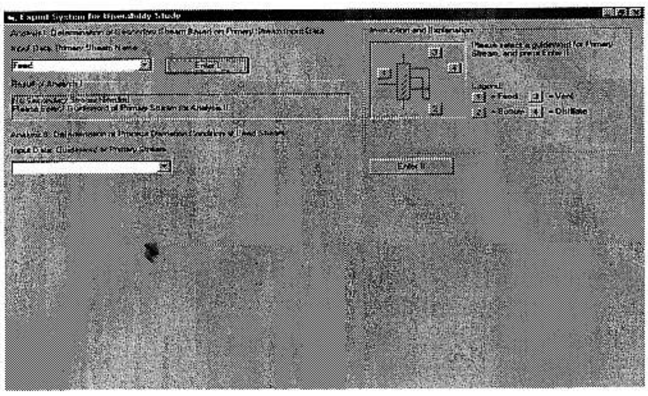

Figure 4 - Result of Analysis I for Feed Stream

Figure 4 shows the first result after the feed stream has been selected as the primary stream. After a guideword is selected, and the "Enter II" command button has been clicked, the program continues to find immediate process deviation relationship as shown in Figure 5.

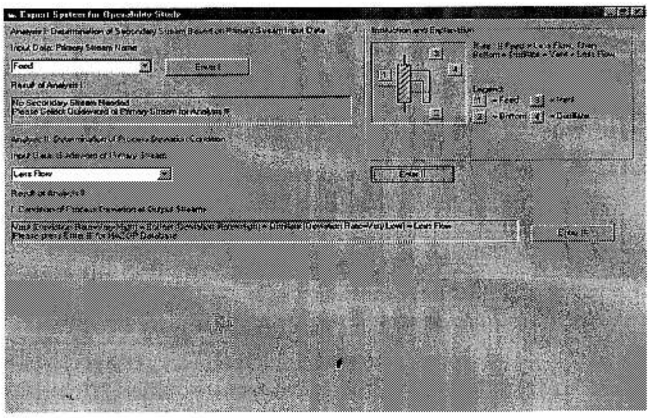

Figure 5: Result of Analysis II for Feed Stream (Less Flow)

From Figure 5, if the less flow (True Rules Category) is selected for feed stream, each output streams will be identified as the consequences, which produce the less flow deviation as well. Consequently, all the output streams shown in the justifier area, will be colored in yellow. Then, the user will be asked to click the "Enter III" command button to perform the main causes and consequences as well as the side consequences of HAZOP study related to process deviation relationship as shown in Figure 6.

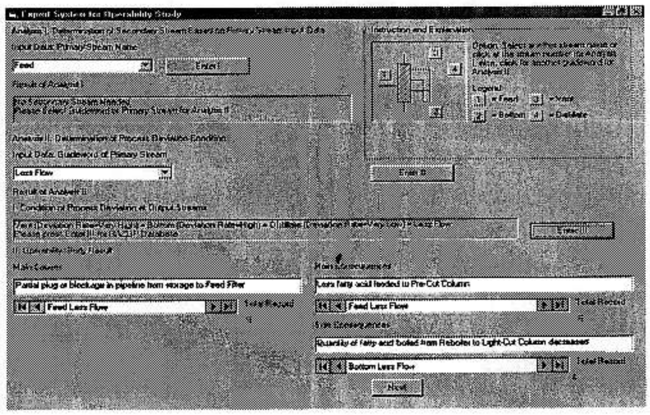

Figure 6 - Result of Analysis III for Feed Stream (Less Flow I)

In this case, the main causes and consequences provided in Figure 6 are related to the less flow deviation of feed stream, which is the main guideword selected to be analyzed. On the other hand, there are two databases of side consequences provided; consequences of less flow in bottom stream (Figure 6 and Figure 7).

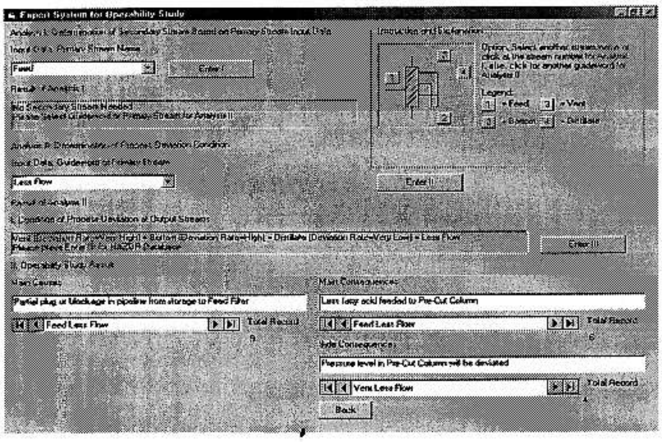

Figure 7 - Result of Analysis III for Feed Stream (Less Flow II)

From Figure 7, the side consequences is the consequences of less flow in vent. This result is an example of the main output structure for 'True Rules Category', and it is based on the result of analysis II, where less flow deviation in feed stream identified has produced high deviation rate in bottom and vent stream (output streams).

Besides, user may also select another guideword for the same stream in order to perform another mode of analyses. For example, Figure 8 shows the complete less pressure result for feed stream.

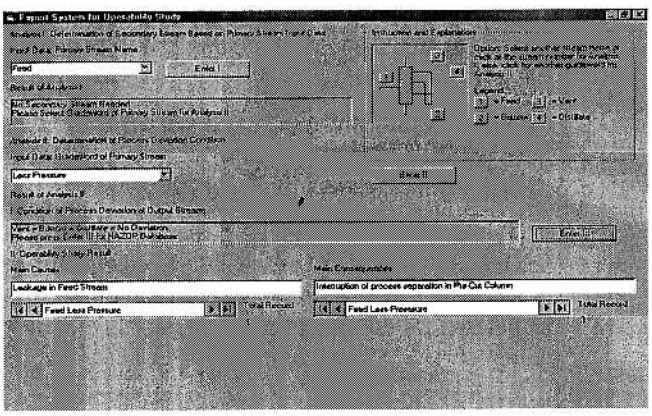

Figure 8 - Result of Analysis III for Feed Stream (Less Pressure)

Figure 8 shows an example of the complete advisory system's result structure for 'False Rules Category' (e.g. less pressure). The rules of 'False rules Category' will identify no process deviation relationship between feed and bottom. As a result, there will be only the main causes and consequences related to the less pressure guideword provided in Figure 8. There will be no side consequences produced as all the output streams conditions are defined as "No Deviation".

Vent Stream Results

The same basic procedures as in the feed stream analysis are applied to the output streams. For example, the result of analysis I for vent stream is shown in Figure 9.

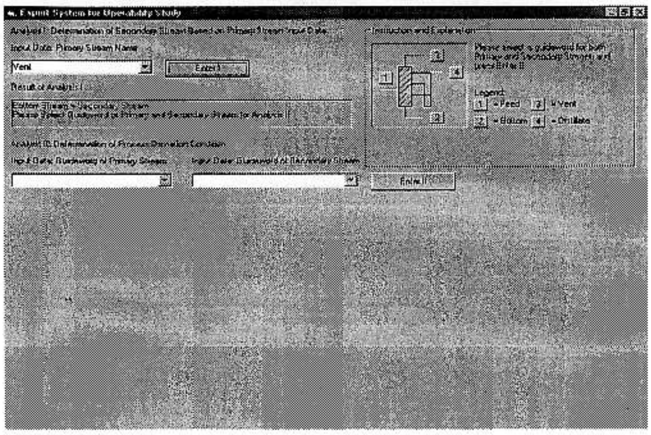

Figure 9 - Result of Analysis I for Vent Stream

From Figure 9, the bottom stream is identified as secondary stream for the vent stream analysis. There are also two input boxes shown in the user interface, particularly for the selection of a guideword for both primary and secondary stream specified. As an example, the less flow deviation is selected as the guideword for both primary and secondary stream and the result is shown in Figure 10.

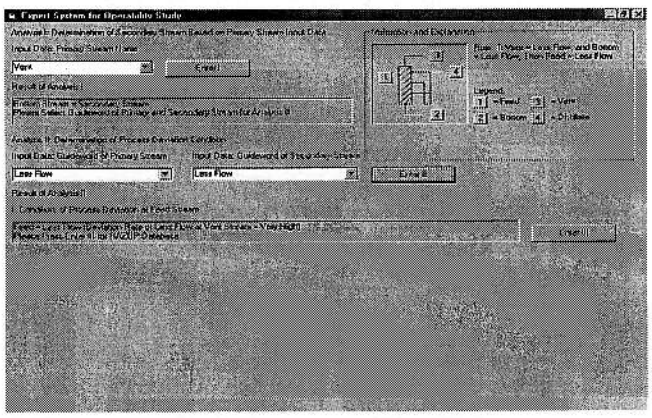

Figure 10 - Result of Analysis II for Vent Stream (Less Flow-Less Flow)

From Figure 10, the result shows "Feed Stream = Less Flow (Deviation rate of less flow at Vent Stream = Very High)", meaning that the less flow condition of feed stream has been identified as a cause to produce the less flow deviation in the bottom stream. Finally, after the 'Enter III" command button has been clicked, all the related causes and consequences from HAZOP study will be displayed as shown in Figure 11.

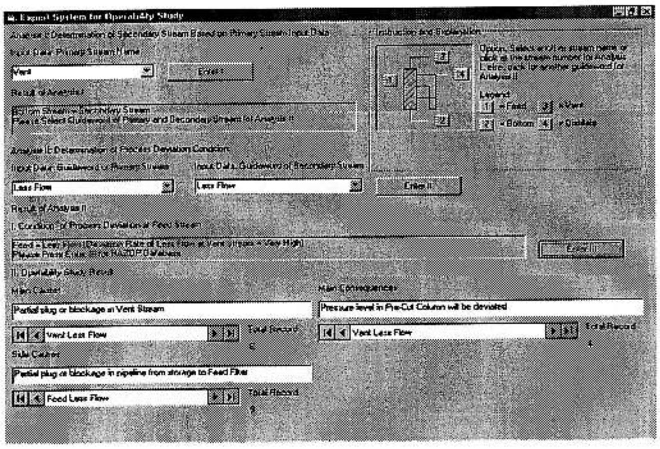

Figure 11 - Result of Analysis III for Vent Stream (Less Flow-Less Flow)

From Figure 11, the main causes and consequences are related to the less flow, which has been selected as guideword for the vent stream before, while, the side causes is obtained from the less flow causes of feed stream database. These databases are given as the result of less flow in feed stream is identified to produce the less flow deviation at vent stream, which is shown in the analysis II before. In general, this is the main analysis structure of the 'True Rules Category' that developed for all the output streams in the advisory system. However, the analysis structure of the 'False Rules Category' (e.g. less flow-less temperature) is different as shown in Figure 12.

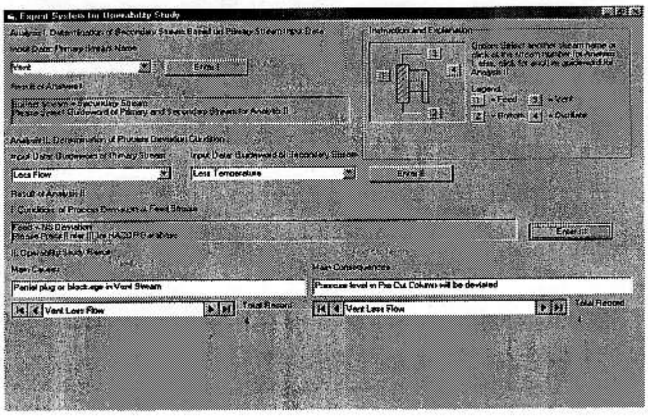

Figure 12 - Result of Analysis III for Vent Stream (Less Flow-Less Temperature)

From Figure 12, the program will show only the main causes and consequences of less flow for vent stream as the final result. There are no side causes databases given, as the program has identified no deviation in the analysis II result.

Discussion

From all the results obtained, it has been found that the modified HAZOP has introduced a new database structure, in which the causes and consequences from conventional HAZOP study have been categorized into 'main' and 'side' causes or consequences respectively. The 'main' causes and consequences are related to the main analyzed guideword, meanwhile, the 'side' causes or consequences are correlated to the process deviation from other study nodes, which produce a process deviation relationship with the analyzed guideword.

Comparison of Modified HAZOP with Conventional HAZOP Structure for Feed Stream

In general, for each guideword specified in the conventional HAZOP study, the causes and consequences are determined using the brainstorming approach. If all have been identified, then another guideword or study node will be examined in sequence, however, the relationships among them are not specifically being analyzed. As a result, each guideword analyzed produces only one list of causes or consequences.

On the other hand, after the modified HAZOP algorithm has been applied, the structure produced is different. The result shows that less flow deviation of feed and vent is connected with each other to produce a process deviation relationship. Particularly, less flow deviation from feed stream is identified to produce less flow deviation in vent stream. As a result, the main causes of less flow in feed stream is connected to the main consequences of less flow in vent stream, in which the main consequences of less flow in vent stream is identified as 'side' consequences. This result is shown in the Figure 7 earlier.

In conclusion, from the study, the main improvements made by the modified HAZOP are:

1. Two of study nodes in the conventional HAZOP study have been connected together, whereby both of them are being separated in the conventional HAZOP study before.
2. Both of the study nodes are connected through the guideword, whereby the process deviation relationships can then to be obtained.

Consequently, a new documentation structure as well as comprehensive HAZOP database is produced, where the databases of causes and consequences from other study nodes can be used for the study node under consideration.

Conclusion

In summary, it can be concluded that, the advisory system developed has been proven to demonstrate as well as to support the modified HAZOP algorithm proposed. The advisory system provides an interactive-user friendly interface and a simple analysis, for the user to understand as well as to present the modified HAZOP study.

Acknowledgements

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