Integrating HAZOP and LOPA...can result in exceptional benefits

D ue to compressed project schedules, limited staff accessibility and engineering cost pressures, many companies want to integrate their HAZOP and SIL / LOPA studies. This is not surprising, as the IEC 61511 Functional safety - Safety instrumented systems for the process industry sector standard promotes a tight relationship between the two. However, since this approach is still relatively new in the safety and risk assessment tool kit, the practice is open to some misinterpretation and in consequence, to misapplication and thus questionable results.

The root cause of most problems is that HAZOP is a cause-based method and LOPA is a consequence-based method. By trying to perform HAZOP and LOPA concurrently, risk assessment practitioners are virtually forced to adopt a cause-based approach for both methods. This compromises the value of the entire exercise and can lead to severely flawed results.

A bit of background

HAZOP and Operability or HAZOP studies identify and assess the hazards and operability issues in existing and new facilities. HAZOP is a qualitative type of risk assessment. According to the IEC 61882 Hazard and Operability Studies standard, the purpose of a HAZOP is to identify:

- Potential hazards in the system. The hazards involved may include both those essentially relevant only to the immediate area of the system and those with a much wider sphere of influence (e.g. some environmental hazards);
- Potential operability problems with the system and in particular identifying causes of operational disturbances and production deviations likely to lead to nonconforming products.

In summary, HAZOP is a cause based method and a good tool for identifying causes and consequences for hazardous events.

Let’s now look at the Layer of Protection Analysis (LOPA) method of Safety Integrity Level (SIL) Determination. It is a semi-quantitative risk analysis technique that considers the reliability of safeguards applicable to a specific cause-consequence scenario in terms of probability of failure on demand (PFD) of each safeguard and the protection layers. The total amount of risk reduction provided by these protection layers is then defined and the need for more risk reduction determined. If additional risk reduction is required and if it is to be provided by a Safety Instrumented Function (SIF), for example, the LOPA method specifies the precise amount of risk reduction required by the SIF. This risk reduction can also be expressed in terms of Safety Integrity Level (SIL) and ranges from SIL 1 (the lowest) to SIL 4 (the highest).

In essence, LOPA is a consequence-based method and a good technique for working with the consequences and identifying the adequacy of the safeguards, or lack of them.

Example LOPA

To illustrate the fundamentals of a proper LOPA analysis, consider the following situation where a distillation column has an overhead reflux stream. If the cooling stream is lost, the tower will overpressure, eventually rupture and cause an uncontrolled loss of containment. Two possible initiating events or causes of the loss of reflux (the consequence) were identified in the HAZOP - a closed reflux valve and a reflux pump failure. In addition, four protection layers were identified, each with a defined PFD value. The resulting LOPA calculation in Figure 1 below shows how the PFD for the Safety Instrumented Function (SIF) would be calculated.

The key issue to note in the Figure 1 example is that there were two causes identified for the same consequence and each cause-consequence pairing had a unique set of protection layers.

Single biggest mistake

The single biggest mistake many risk assessment practitioners make is trying to perform HAZOP and SIL / LOPA concurrently in the same team meeting. They think an integrated HAZOP and SIL / LOPA means performing the HAZOP and SIL / LOPA concurrently with the same team. By doing so, they are virtually forcing the team to adopt a cause-based approach for both methods. While this approach is acceptable when there is a one-to-one pairing between cause and consequence, in instances where there is more than one cause for the same consequence, this approach is not accurate. Instead, it is only when there is a rigorous examination of all causes which result in the same consequence that the benefits of integrated HAZOP and LOPA can be fully realized.

Recommended practice

The best approach is to conduct the HAZOP and SIL / LOPA in separate sessions where the HAZOP is conducted first, followed by the LOPA. The HAZOP session is kept focused. The meetings are completed in as little time as possible and the HAZOP team is not confused trying to understand and use the SIL / LOPA method. Typically, the SIL / LOPA session lasts 25 - 35% of the HAZOP duration.

In summary, the work process for successfully integrating HAZOP and SIL / LOPA methods is:

1. Perform the HAZOP. Comprehensively identify all the causes, consequences and safeguards.
2. All causes resulting in the same consequence should be identified and analyzed by an experienced LOPA analyst. This should be done off-line. Remember that if this is not done or is done incorrectly, it invalidates the assumption that HAZOP and SIL / LOPA will provide accurate results.
3. Perform the LOPA review. The LOPA team should be led by a LOPA expert and include an experienced operator, a process engineer and an instrument - electrical maintenance person.

However, the real practical challenge of effectively integrating HAZOP and SIL / LOPA studies, once the three steps are followed, is in documenting and managing the vast amounts of data generated by the process. When documenting the study results of large projects where HAZOP studies takes weeks and create hundreds of recommendations, doing this work accurately and efficiently takes on a whole new meaning.
For example, Figure 2 shows a screen shot where HAZOP data, taken from either a MS-Excel, MS-Word or a commercial PHA software package has been imported into SilCore™. The yellow high-lighted areas show that two causes have been identified for the same consequence. Ensuring that the HAZOP data has been accurately inputted into the front end of the SIL / LOPA is possible with a software package that has “data mapping” functionality. Such a feature virtually eliminates the potential for data entry error and provides a huge productivity boost when doing integrated HAZOP and SIL / LOPA studies.

In Figure 3, for the same consequence (e.g. potential liquid carryover to K101 resulting in compressor damage), the information is captured in the LOPA table and the relevant causes, initiating event frequencies (likelihoods), consequences, protection layers and their PFD values are documented. The information is displayed for easy understanding. The screen also shows the TF and MF values and the amount of risk reduction necessary to mitigate the residual risk. There is more than a passing similarity to the simplified table shown in Figure 1. While it is true that the SIL / LOPA calculations are relatively simple, because there are so many scenarios to consider and work through, well designed and easy-to-use software tools are essential for accurate, comprehensive and productive analysis.

In our experience, there is a gap in the marketplace’s tools today for conducting integrated HAZOP and SIL / LOPA studies which allow the user to analyze all causes for a given consequence. This led to our developing a software tool called SilCore™, designed to fully integrate the HAZOP the SIL / LOPA, the SIL Verification and Safety Requirements Specification (SRS) process into one database, so you don’t have to deal with the hassles of multiple spreadsheets. Compared to the traditional spreadsheet method, SilCore™ users can realize savings of at least 50% of their time, even more for large numbers of scenarios.

Remember, used separately, HAZOP and SIL / LOPA techniques are powerful methods for evaluating and improving the safety of process facilities. However, they need to be carefully integrated so the results are meaningful and comprehensive. A trained risk assessment specialist, with a robust software tool, can provide solid, cost effective solutions.

SilCore™ is an integrated HAZOP - SIL / LOPA software package and is commercially available to the general marketplace. The work process and theory behind LOPA can be downloaded from ACM’s website at http://www.acm.ab.ca. Readers can contact the author, Ken Bingham of ACM Facility Safety, a division of ACM Automation Inc. for more information by email: ken.bingham@acm.ab.ca and by phone at 403-264-9637.